SPACELAB USER INTERACTION STUDY

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PHASE 2 REVIEW
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SPACELAB USER INTERACTION
PHASE 2 REVIEW

AGENDA

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INTERACTION

The quantity of data associated with the Spacelab experiment program will far exceed that of any prior space program. The cost effective generation, processing, and utilization of this data is therefore becoming of increasing importance in data management system design. The use of man's real time decision making ability is a major step in that direction. In order to realize all its advantages, this thought process, called interaction, must be relatively unstructured procedurally and unconstrained by hardware. The lack of rigid structure allows man-involvement to apply judgment functions tailored to a nearly unpredictable need. Implicitly, man has the overview of the data generation and collection function, and can react in near-real-time to accomplish those parts of the objective which are within his capability. It is not the intent of interaction that man or the hardware at his control merely sort data in near-real-time as it is generated, but to provide the look-back and look-ahead capability to place operations and data flow in the proper context of user needs. Interaction uses man as the manager and the modifier of the essential structure and plans that must be a part of any space operation.

INTERACTION

- CONTROL OF SCIENTIFIC OR ENGINEERING DATA TO BE COMPATIBLE WITH:
  - -- COST OBJECTIVES
  - -- USER NEEDS
  - -- COMMUNICATION RESTRICTIONS

- MANUAL (MAN-IN-THE-LOOP)
  - -- TARGET SELECTION AMONG SEVERAL SIMILAR
  - -- SCIENTIFIC VALUE OF DATA JUDGEMENTS

- AUTOMATED
  - -- PRE-DEFINED REJECTION CRITERIA (CLOUDS, NOISE BACKGROUND, ETC.)
  - -- IN-ORBIT
  - -- GROUND OVERRIDE FOR SPECIAL PURPOSE UTILIZATION

OBJECTIVES OF INTERACTION

All of the objectives identified for interaction are related in one way or another to efficiency and cost. Those listed opposite form the principal investigative purpose of this study. Some are obvious; e.g., reduction, evaluation and verification prior to collection. However, the method of implementation and the value realized are not obvious. The thrust of the study effort is to formulate the available options and to identify the value potential of each.

OBJECTIVES OF INTERACTION

- EXPERIMENT OPERATION REDIRECTION
- EVALUATION OF PERFORMANCE AND PROCEDURES
- VERIFICATION OF INFORMATION OBJECTIVES
- ENHANCEMENT OF INFORMATION QUALITY
- REDUCTION OF DATA VOLUME WITHOUT SACRIFICING NEEDED INFORMATION
- GROUND DATA PROCESSING SUPERVISION AND CONTROL
- OVERALL REDUCTION OF INFORMATION COST

INTERACTION STUDY FLOW

The primary objective of the Spacelab User Interaction Study is to develop a baseline of credible interaction benefits measured against additional system costs. The study plan for meeting these objectives consists of a three phase approach that includes:

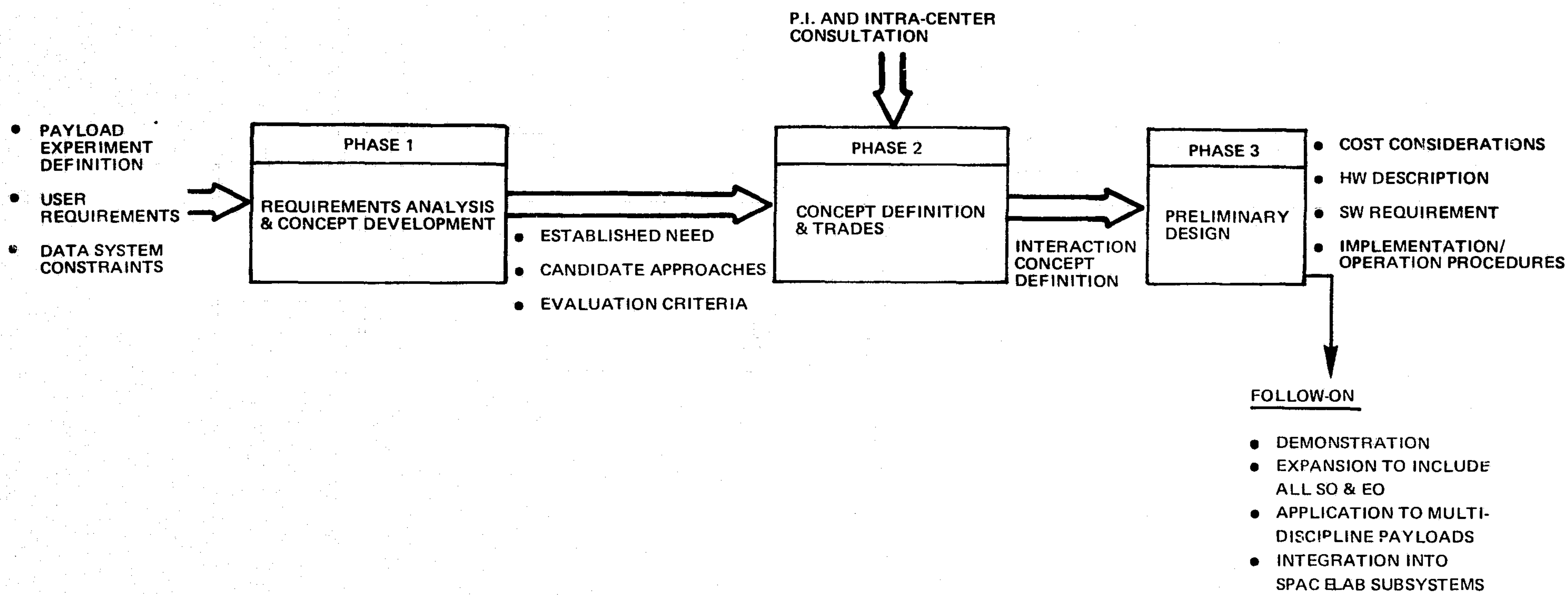
Phase 1	-	Requirements analysis and concept development
Phase 2	-	Concept definition and trades
Phase 3	-	Preliminary design

Phase 1, completed in 1974, utilized experiment payload descriptions and performance requirements defined by the Spacelab Phase B effort together with projected user performance plans and analysis requirements to establish the need for interaction, develop candidate approaches, and determine evaluation criteria.

The Phase 2 output, reported on in this document, provides interaction concept definition. This work resulted from extensive principal investigator and intra-center consultations along with hardware/software and ground/onboard functional allocation trades.

Interaction implementation is determined in Phase 3. The hardware modifications are to be described, software requirements written and an evaluation of the cost of implementation made.

INTERACTION STUDY FLOW



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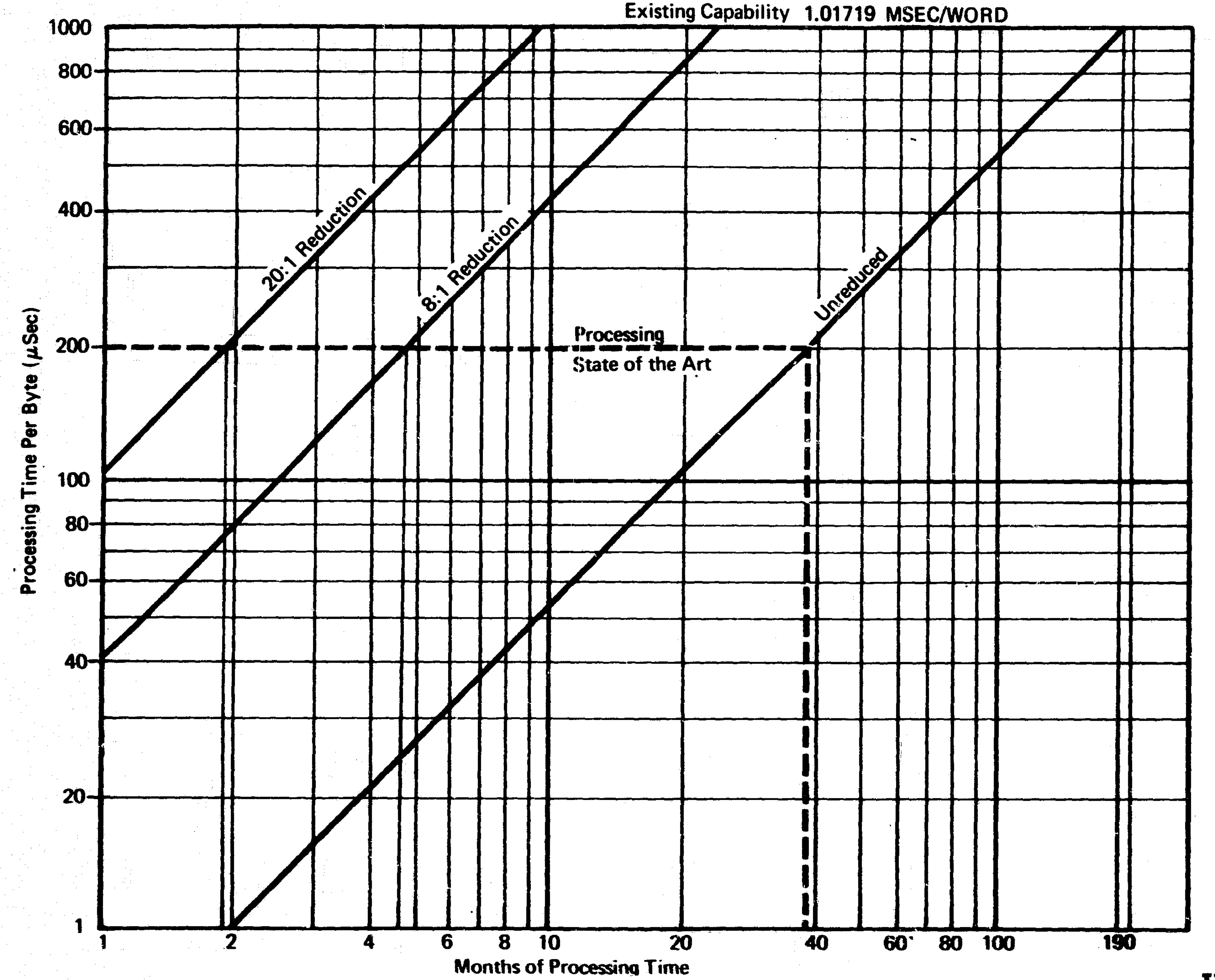
THE NEED FOR INTERACTION

Two methods exist by which the data volume expected from Spacelab missions can be handled -- faster computers and/or less data. The chart opposite shows how both will be required to meet future data handling needs. Five Spacelab missions were chosen to determine how long it would take the four major NASA Processing Centers (MSFC, GSFC, JSC, and JPL) to process the data. Using all the prospective advantages available (except possible software improvement), processing time was reduced from 186 months to 4.8 months and 1.8 months assuming 8:1 and 20:1 interactive data reduction respectively; this on top of a 5:1 improvement in computer speed. The disciplines represented by the five Spacelab payloads used in this assessment are:

- Earth Observation
- Atmospheric and Space Physics
- Earth and Ocean Physics
- Solar Physics
- Space Technology

These five payloads represent 56% of the Spacelab missions, with a maximum of 28 payloads planned for any given year. All 28 payloads (one launch per 13 days) will require a "best case" processing time of approximately 10 months.

THE NEED FOR INTERACTION



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POTENTIAL GAIN THROUGH INTERACTION

Based on the data flow for Spacelab by discipline and a combination of Skylab experience and experimenter plans, an assessment has been made of the data reduction benefits expected from interaction. Reductions of data shown for the non-viewing experiments (e.g., physics, communications/navigation, technology, life sciences and material sciences), are due primarily to procedural flexibility. The primary benefit in these cases is not the reduction of data per se but the savings in experimenter and mission time due to visibility and control over each step of the operation. The time saving was converted to data quantity that would otherwise be required and the reduction calculated.

Benefits for the viewing experiments (e.g., astronomy and earth observations) are due primarily to the reduction of data bulk by visually verifying data quality prior to data store. Experiment knowledge and proper control are used to eliminate unnecessary to erroneous data while capturing the information and maintaining quality.

POTENTIAL GAIN THROUGH INTERACTION

DISCIPLINE	DIGITAL DATA ACCUMULATION (BITS/MISSION)	INTERACTION REDUC. RATIO	DIGITAL DATA (BITS/MISSION)	FILM (FRAMES/MISSION)
MATERIAL SCIENCE	1.3×10^{10}	10	1.3×10^{9}	
PHYSICS	16×10^{10}	4	4×10^{10}	1,000
COMM/NAV	2×10^{9}	2	1×10^{9}	300
TECHNOLOGY	4×10^{10}	2	2×10^{10}	7,000
ASTRONOMY	3.5×10^{10}	4	8×10^{9}	117,000
LIFE SCIENCES	2.7×10^{10}	(DIGITAL ONLY) 10	2.7×10^{9}	3,600
EARTH OBSERVATIONS	4.2×10^{12}	8	5.4×10^{11}	25K

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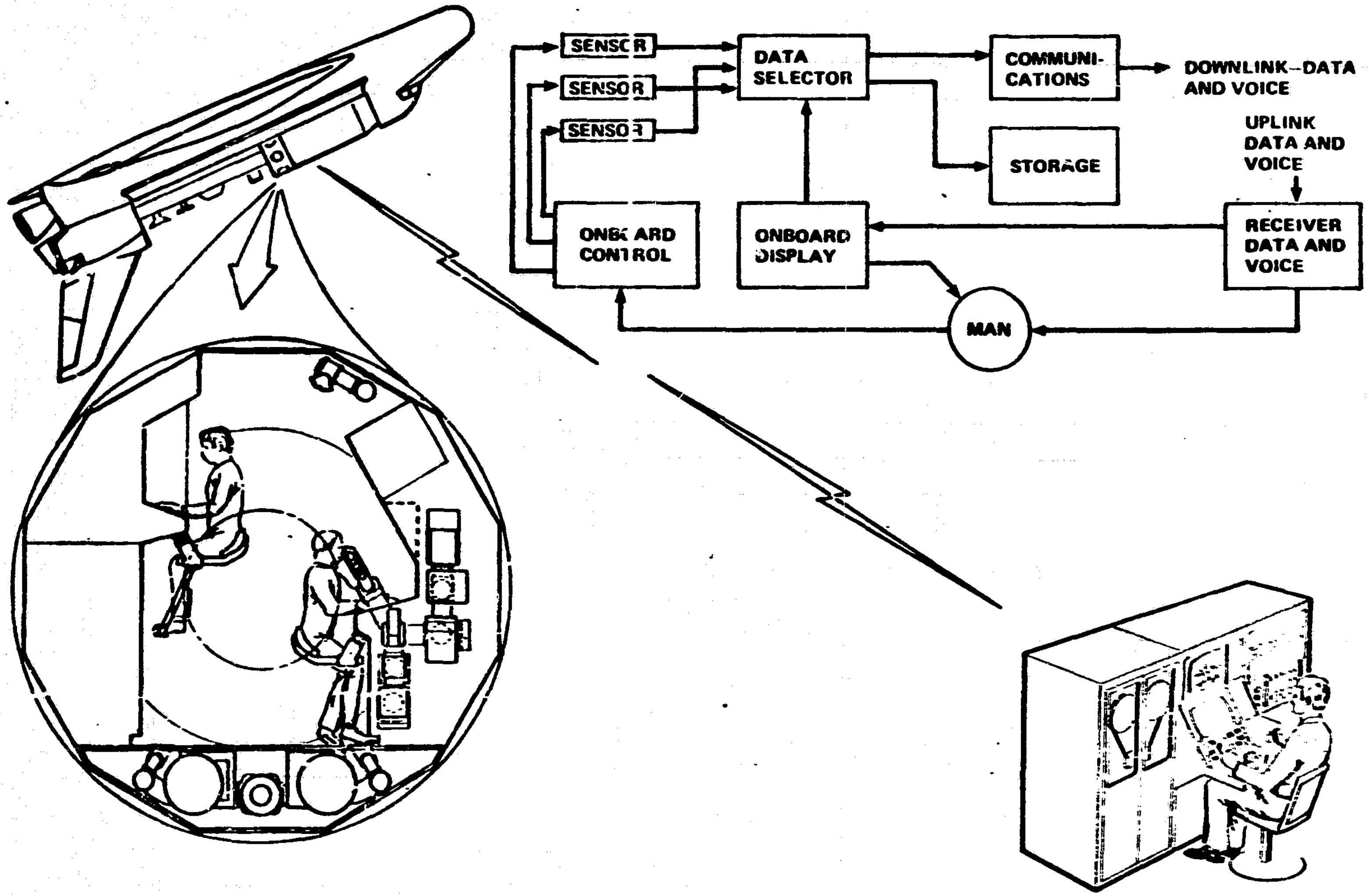
SELECTED REAL-TIME USER INTERACTION CONCEPT

The selected concept for experiment control will utilize the onboard experimenter (probably would be a graduate student type) interfacing with the actual equipment and in the ground monitoring making the primary decision as to which data contains useful information. This concept was selected because: 1) selection of data is not critical, 2) there is significant time within the TDRSS to allow the raw data to be received at a control center, 3) and standard off-the-shelf hardware makes information available to many scientists rather than just one. Selecting data by using interaction will minimize the amount of data that needs to be preprocessed and allow extraction of information at a minimal cost. The implementation of a total interaction system onboard would entail development of high resolution display devices, and second, the total expertise would not be available onboard to make data selection decisions; therefore, not maximizing the data selection within the system and still causing a problem of having too much data to process on the ground. It is further found that scientists probably will not fly and would send their associates. This would create a great deal of concern because the lead scientist has not evaluated data that could be thrown away. By allowing ground interaction and ground data selection, you maximize the amount of data that is thrown away; thereby, minimizing the amount of data required to be processed for each experiment which is very important since the missions are only six days of experiment operations.

SELECTED REAL-TIME USER INTERACTION CONCEPT



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INTERACTION CONCLUSIONS

Interactions can be classed either as data or information interactions. In data interactions the interaction is based primarily on raw data and with respect to data generation. Information interactions imply content judgement or decisions. Operations called for will be allocated either onboard or on the ground as a function of the relative significance of; cost, time requirements and resource availability.

Where possible, interaction should be applied prior to recording. The closer to the collecting element interaction can be applied the better data can be eliminated without consuming resources. The availability of TDRSS will determine to a great extent final ground/onboard functional allocations. Ground based data screening is eliminated with onboard interaction. Interaction implementation will involve the use of standard hardware as much as is practical.

Real time onboard interaction will dominate experiments requiring target or phenomenon selection with limited communication capability. Ground based interaction will offer more extensive processing capability and scientific expertise.

Reduction factors achievable have been estimated for interaction applications. These reductions range from 2:1 for the space technology discipline to 10:1 for the space processing discipline. These estimates were conservatively based upon the reductions which might be allowed by the scientific investigators while retaining the scientific information. It is further estimated that a reduction on the order of 30:1 would be required for the projected data outputs to be processable by present capability.

INTERACTION CONCLUSIONS

- DATA COLLECTION
  - -- APPLIED PRIOR TO DATA RECORDING -- GROUND OR ONBOARD
  - -- COMMUNICATION CONSTRAINTS DETERMINE LOCATION
  - -- INTERACTION PROPERLY APPLIED ON-LINE ELIMINATES OFF-LINE SCREENING
  - -- IMPLEMENTATION WILL INVOLVE STANDARD HARDWARE
- INFORMATION COLLECTION
  - -- TARGET/PHENOMENA SEARCHING REQUIRES REAL TIME OPERATION
  - -- COMMUNICATION/SYSTEM DELAYS FORCE DECISION ONBOARD
  - -- GROUND IMPLEMENTATION OF INFORMATION EXTRACTION IS SIMPLER
  - -- MORE EXPERTISE AVAILABLE ON THE GROUND
- REDUCTION FACTORS ACHIEVABLE
  - -- FROM 2:1 (ST) TO 10:1 (SP); CONSERVATIVE ESTIMATES
  - -- HIGHER GOALS NEEDED: 30:1 MINIMUM

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PHASE 2 APPROACH

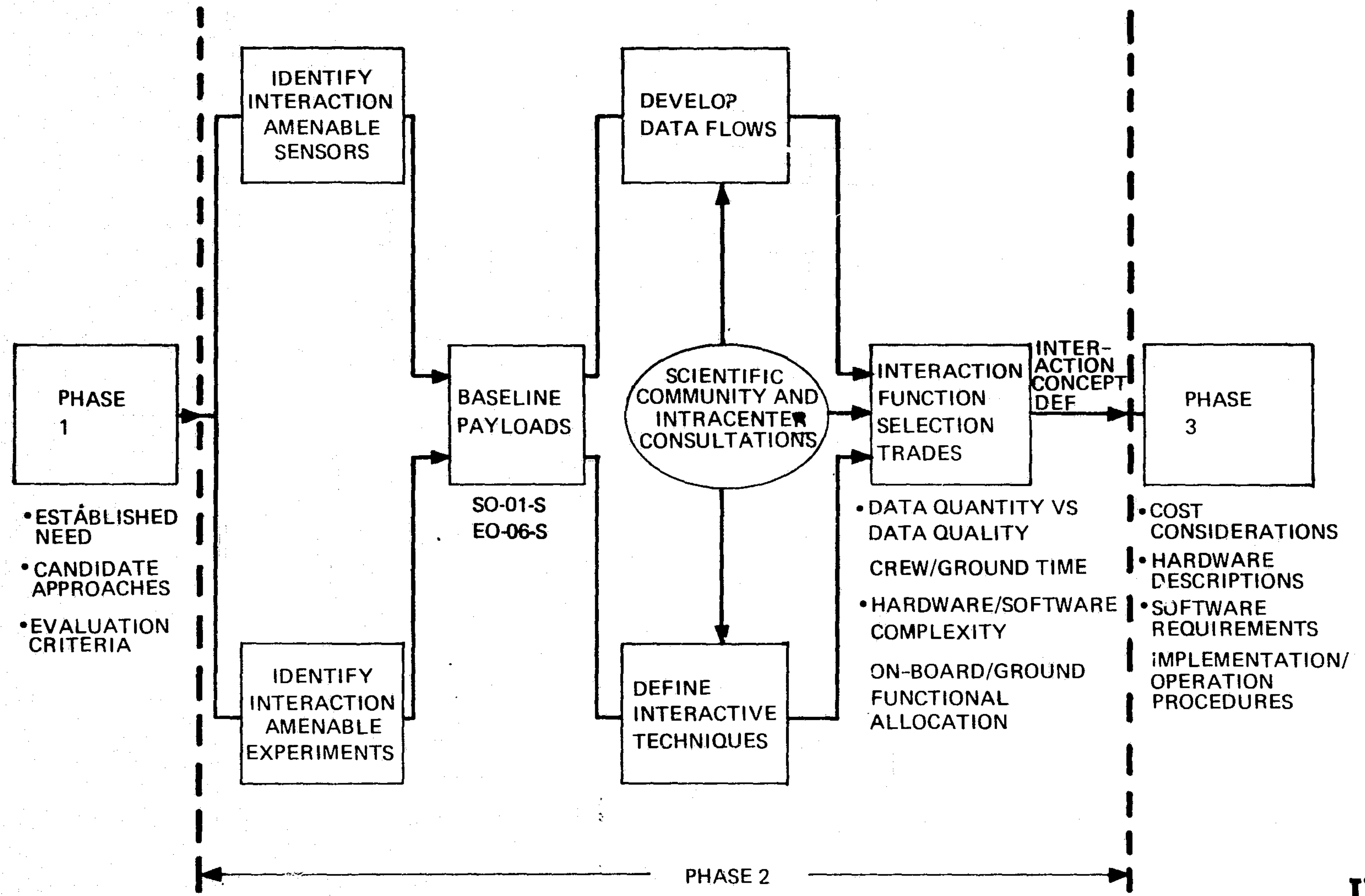
The objective of Phase 2 is the definition of feasible interaction concepts. The feasibility established based on Phase 1 considerations: 1) improvement of information to data ratio, 2) impact of crew/ground time, and 3) cost of hardware/software complexity. The approach was based on developing techniques for specific reference missions as opposed to a general approach of applying interaction in a qualitative manner to all classes within the realm of defined missions. This study philosophy provides for a specific demonstration of interaction.

The first step in this study phase was the selection of baseline design reference missions. This task was initiated by reviewing Spacelab experiment and sensor characteristics. These were classified in terms of data output format, information content, and experiment objectives. Based on this data, the two payloads selected were EO-06-S (Earth Observation) and SO-01-S (Solar Physics). The selection being driven by: 1) application across all payloads and 2) amenability to interaction.

Science data flow and interactive techniques were then developed for the two baseline missions. A key part of these activities was the interviews with interested personnel at Harvard College Observatory; Johnson Space Center; Goddard Space Flight Center; Naval Research Lab; IBM facility in Gaithersburg, Maryland. Regional visits included the Top of Alabama Regional Council of Governments, Huntsville, Alabama; Tennessee State Planning Office, Nashville, Tennessee; and the Alabama Development Office, Montgomery, Alabama. In addition, discussions were held with local (Marshall Space Flight Center) personnel that had prior experience with data systems. By sampling the concerns and desires of previous users of satellite data, practical aspects were introduced into the data flow and interaction concepts.

Functional allocation and/or selection trades were then made to produce the interactive technique definition required for Phase 3. The effect on data quantity and data quality of each technique was assessed. The amount of crew and/or ground involvement as well as hardware/software complexity are also important with some type of cost levied in each case. Onboard/ground functional allocation is made in each case.

PHASE 2 APPROACH



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BASELINE DEFINITION

The utilization of the indicated payloads as the study baseline was based on their general applicability to all Spacelab missions and on their amenability to interaction. It was felt that these payloads offered the most potential for allowing numerous interaction techniques that would be adaptable to other payloads. The selection was based on a review of the Spacelab Instrumentation Handbook (IBM No. 74W-00263) and the Level B Payload Description data and considered areas like: experiment/payload objective, number of flights, instrument complexity, data rates, data form, target, and data flow.

SO-01-S

This payload is a dedicated solar sortie mission. It will have two scientists and two experiment technicians as part of a seven man crew. Its objective is to observe solar flares, related active phenomena, and flare emissions. It will also observe solar atmospheric properties and qualify large solar observatory instrumentation technology. The analysis concentrates on the photoheliograph which is characterized by: 12 MBPS digital output, 8,000 frames/day film utilization, image outputs in UV, white light, and NIR, and TV display for crew/ground display and pointing.

EO-06-S

The mission objective is the earth resource mapping of land masses. There are 17 sortie flights (1980 - 1991) projected with a nominal flight duration of 7 days. Thirty observation intervals of .25/hr each is assumed. The onboard data handling equipment includes a spectrometer assembly (multi-spectral scanner), a spectrometer data handler (video processor, holding memory, shift registers), and a wideband tape recorder. The data rate could be as large as 240 MBPS. All data is to be returned to the ground; there is no real time transmission nor on-orbit dump.

BASELINE DEFINITION

SO-01-S (SOLAR PHYSICS)

- SOLAR VIEWING EXPERIMENTS
- SEVERAL REPRESENTATIVE INSTRUMENTS
- PALLET ONLY CONFIGURATION; ON ORBIT CONTROL
- DIGITAL (13.2 MBPS) AND FILM (786 FR/ORBIT) DATA

EO-06-S (EARTH OBSERVATION)

- EARTH VIEWING WITH SCANNING INSTRUMENT
- EARTH RESOURCES DETECTION AND IDENTIFICATION
- PALLET ONLY CONFIGURATION; ON ORBIT CONTROL
- DIGITIZED IMAGE DATA

- AVAILABLE EXPERIENCE REFERENCE
- CROSS SECTION OF INSTRUMENTATION
- MULTI-DISCIPLINE
- VIEWING AND NON-VIEWING
- VIDEO, FILM, AND DIGITAL DATA
- AMENABLE TO TECHNIQUE DEMONSTRATION

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SURVEY TRIP -- HARVARD COLLEGE OBSERVATORY

On December 6, 1974 a meeting was held at the Harvard College Observatory for the expressed purpose of obtaining scientific data user point-of-view with respect to interaction. The discussion was between IBM personnel and the following HCO personnel:

Dr. Bill Harby, Dr. J. G. Timothy, Dr. George Withbroe, Alice d'Entremont, Nate Hazen

Since HCO had developed the S055 EUV Spectrometer flown on Skylab and are presently analyzing data from the experiment, their critique of the Skylab operation plus their concept of how experiments should be run in the future are of great interest in this study.

Eleven points were made concerning the HCO desires in future missions. These are summarized in IBM memo number 74-227-044. Seven of those were interaction related and are supportive of the concepts we are currently developing. These include:

- Solar data must be displayed in real time to the Principal Investigator on the ground. Both graphic and imaged data displays are desired in real time.
- Scientific instrument engineering data should be available from a display near the Principal Investigator. Instrument performance, as determined by the engineering data, is required to evaluate the scientific data. Reprogrammable airborne TM equipment is desired.
- Data Storage should be provided that will permit quick access to all scientific data throughout the mission.
- An "off-line" investigative console, physically near the P.I.'s console, having access to all the stored scientific data collected during the mission is required to maximize the scientific value of the experiment. The console used for this purpose must have color capability, and must permit interaction to control the gray-scale assignments to the various colors, and have the capability to rotate the color table (to accentuate various features of the display).
- A direct communication link between the P.I. and the onboard payload specialist is required. HCO personnel indicated that too often during Skylab, communications became garbled while they were being passed along the organizational setup to the Capcom.
- The P.I. requests a proper division of control capability over the scientific instruments between ground and crew. Hopefully, full instrument operational capability can be provided to the P.I. This capability is especially important if the crew is suffering from motion sickness during the early days of the mission. In that case, the ground could operate the instruments with little or no assistance from the crew.
- Inclusion of a ground lock-out switch on the C&D panel would prevent operating errors from occurring due to dual command inputs (crew and ground). Thus, the crew could take total control of the instrument whenever they were able. This feature should also satisfy the astronauts' desires to be "prime" in payload operation.

SURVEY TRIP SUMMARY

HARVARD COLLEGE OBSERVATORY

- SKYLAB S055 EUV SPECTROMETER
- ALL DIGITAL OUTPUT
- REAL TIME TRANSMISSION/ON ORBIT DUMP
- FUTURE P.I. NEEDS:
  - DATA DISPLAYED IN REAL TIME TO P.I.
  - DATA STORAGE FOR QUICK ACCESS TO ALL SCIENCE DATA
  - OFF-LINE INVESTIGATIVE CONSOLE
  - DIRECT COMMUNICATION BETWEEN P.I. AND ONBOARD SPECIALIST
  - REDUNDANT INSTRUMENT CONTROL CAPABILITY ON GROUND

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SURVEY TRIP -- JOHNSON SPACE CENTER

On February 11-13, a series of interviews were held at Johnson Space Center with individuals closely involved in Skylab mission operations and EREP experiment operation and data analysis. A total of twelve individuals were talked with and the results are detailed in IBM memo number K10-75-001. The discussions all supported the need for interaction with some specifics including:

- There were several instances in which the Flight Control Office wanted to implement various forms of astronaut interaction but there was not time available for developing procedures. The need for better understanding of user requirements and establishing a clean P.I./operations interface was emphasized.

- Scientific data suffered more from insufficient calibration than any other source. The need for experiment design for ease of calibration and real time monitoring of the adequacy of calibration was stressed.

- Capability for real time monitoring of data was mentioned by most sources. EREP P.I.'s indicated that 80% of the data may have been saved if this capability had existed. In addition, the ability to provide target update through real time decision making would have significantly enhanced the scientific value of the data.

- The scientific community must become better educated as to the operational and engineering characteristics of the instruments and conversely the experiment design must consider the processing consequences.

- Captain Paul Weitz, who was a member of the first Skylab crew, related that the astronauts, as a group, agreed that generation of the scientific data must be manageable onboard. He further suggested that very little training would be required to prepare a man-in-the-loop for managing the experiments and their data flow.

SURVEY TRIP SUMMARY

JOHNSON SPACE CENTER

SKYLAB MISSION OPERATIONS

- USER REQUIREMENTS NOT PROPERLY COORDINATED WITH OPERATIONS
- POOR REAL TIME INTERFACE BETWEEN P.I. AND OPERATIONS
- MACHINERY NOT AVAILABLE FOR IMPLEMENTING INTERACTION
- INSTRUMENT CALIBRATION DIFFICULT

EREP OPERATION AND DATA REDUCTION

- MUST DESIGN INTO EXPERIMENTS CAPABILITY FOR REAL TIME MONITORING
- EXPERIMENT DESIGN MUST CONSIDER PROCESSING CONSEQUENCES

EREP P.I.'s

- EFFECTIVENESS HAMPERED BY NOT BEING ABLE TO MAKE TARGET UPDATES
- REAL TIME MONITORING WOULD HAVE RESULTED IN 80% DATA SAVING
- LACK OF CALIBRATION MAJOR SOURCE OF DEGRADED DATA QUALITY

ASTRONAUT (P. WEITZ)

- SUPPORTS MANAGING SCIENTIFIC DATA ONBOARD
- FEELS LITTLE ADDITIONAL TRAINING REQUIRED

SURVEY TRIP -- WASHINGTON D.C. AREA

On March 24-28 interviews were conducted with personnel at the IBM facility in Gaithersburg, Maryland, Naval Research Laboratory (NRL) and Goddard Space Flight Center (GSFC). The major points of interest with respect to user interaction include:

IBM - Gaithersburg

The purpose of the visit was to discuss their work in the area of digital processing of image data and to tour their image processing facility. They have developed a system of software algorithms and hardware elements to effect both image enhancement and correction. The demonstration involved displaying several images and processing them via interactive control. The system basically consists of two CRTs for display and a keyboard for control with peripheral hardware to transform from film to digital data and vice versa.

Naval Research Lab

NRL's Skylab experiments generated film data only. Hence, all their data was stored onboard and ground returned. Indications were the data could just as easily been digitized if advantages were found that could have resulted in more efficient operation. This points to the need for early interaction related data from trade studies. They also expressed concern over the ability to conveniently calibrate the instruments.

Goddard Space Flight Center

Discussions with the Skylab S056 principal investigator revealed a large number of areas in which they feel improvements can be made in future experiment programs. These revolve around doing a more complete system analysis and design job on the scientific data system as well as supplying real time interaction capabilities for data quality enhancement and data quantity reduction.

SURVEY TRIP SUMMARY

WASHINGTON D.C. AREA

IBM - GAITHERSBURG

- DIGITAL IMAGE PROCESSING
- DEMONSTRATION OF IMAGE PROCESSING FACILITY

NAVAL RESEARCH LAB

- SOLAR PHYSICS ON SKYLAB
  - ALL RETURN DATA -- NO INTERACTION CAPABILITY
  - INTERACTIVE PLANNING TO TRADE METHOD OF DATA ACQUISITION (FILM VS. DIGITAL)
  - EMPHASIS SHOULD BE PLACED ON REAL TIME CALIBRATION TECHNIQUES
- SOLWYND AND OSO
  - HIGH INTEREST IN ELIMINATING USELESS DATA
  - WRAP AROUND TAPE RECORDER -- AUTOMATIC EVENT DETECTION

GODDARD SPACE FLIGHT CENTER

- EMPHASIZED TOTAL SYSTEMS APPROACH TO DATA SYSTEMS DESIGN
  - ENGINEERING AND SCIENCE DATA SEPARATE
  - EARLY USE OF DATA FLOW SIMULATION
  - BETTER UNDERSTANDING OF OPERATIONAL ASPECTS OF INSTRUMENTS
- SUPPORTS HCO, JSC AND NRL VIEWS OF NEED FOR INTERACTION

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SO-01-S GENERALIZED DATA FLOW

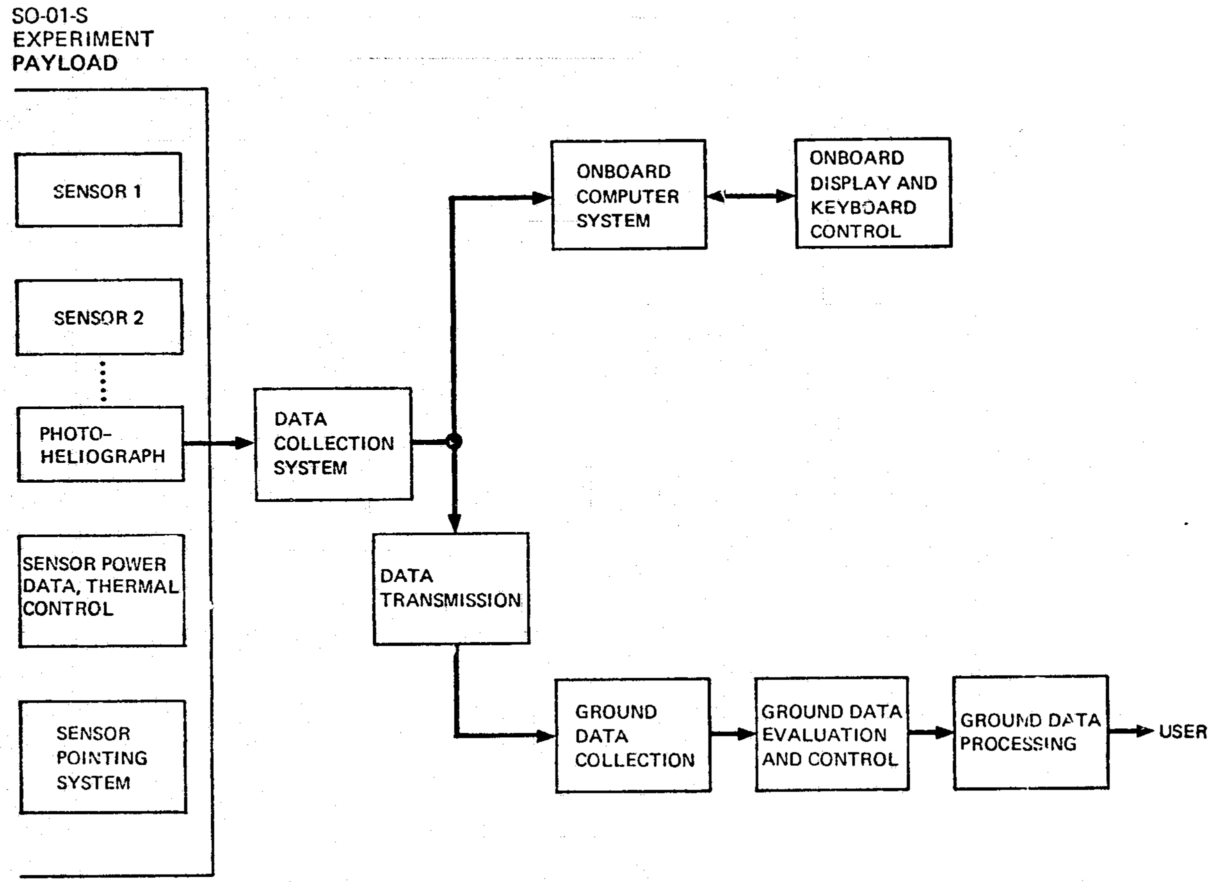
The facing chart contains a diagram for the flow of data for the Dedicated Solar Sortie Mission (DSSM). This payload is the design reference mission for the solar physics discipline. The flow diagram is generalized in that each block represents a standard element in a source to user flow of remotely sensed data.

The SO-01-S payload is comprised of a variety of sensors configured to facilitate solar studies. The photoheliograph was chosen for demonstration purposes and is the data driver for the payload. Level B data sources indicate that the DSSM will involve real time transmission of data as well as onboard storage capability. Data requirements for onboard operations are 13.2 Mbps (digital) and 786 fr./orbit (film). Normally, the flow of digital data would be to the ground via the transmission link or to high speed recorders which are contained within the Spacelab subsystems. This is due to the fact that data is generated by the photoheliograph at a rate exceeding the data bus system capabilities.

Only those elements of the total data system which involve interactive monitoring and responses are included in the generalized flow.

GENERALIZED DATA FLOW FOR EXPERIMENT SO-01-S

- DEDICATED SOLAR SORTIE MISSION
- MULTIPLE SENSORS FOR DESIGN REFERENCE MISSION
- PHOTOHELIOGRAPH IS THE DATA DRIVER
- REAL TIME TRANSMISSION AND ONBOARD STORAGE OF DATA
- 13.2 MBPS AND 786 FRAMES/ORBIT DATA RATES



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SO-01-S TECHNIQUE NO. 1: OPERATIONAL STATUS MONITOR

Functional Description

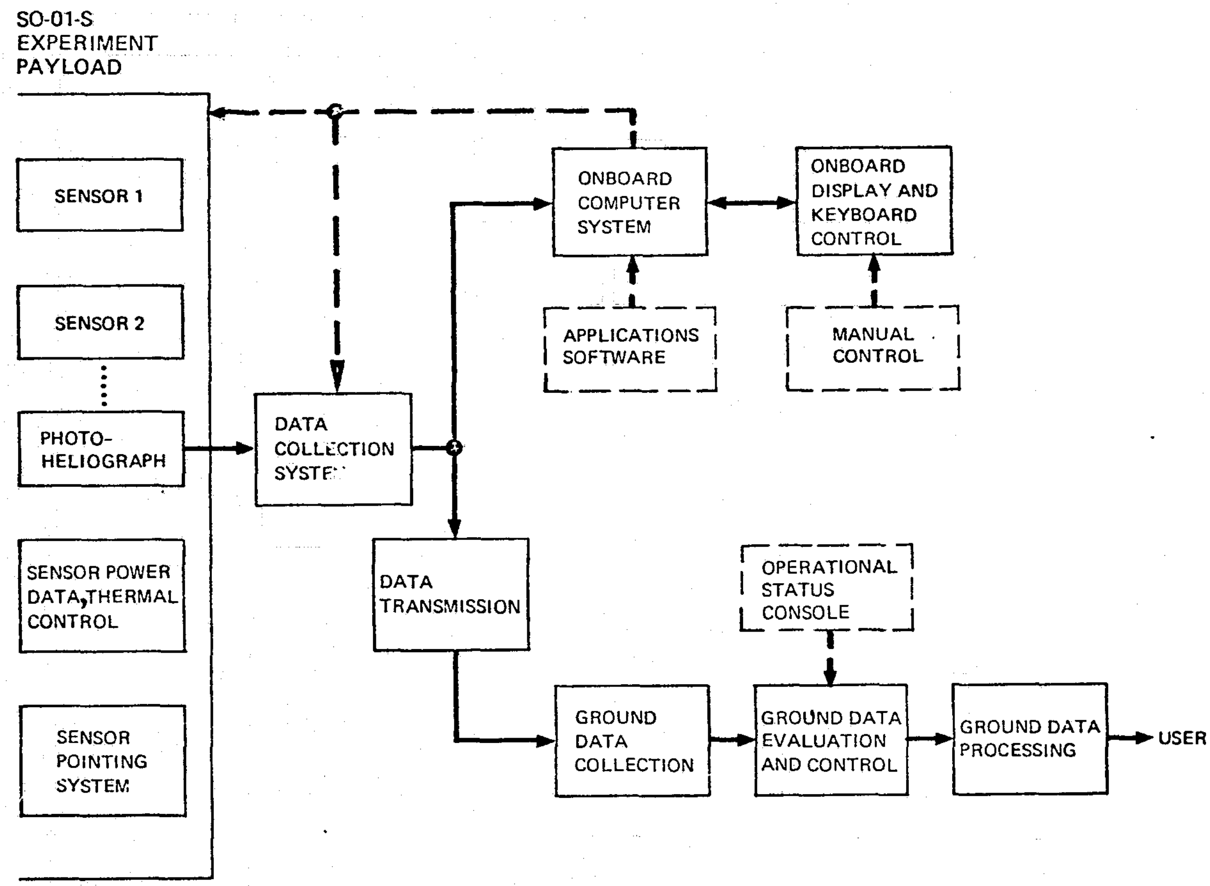
This technique would involve monitoring selected engineering parameters from the instrument to determine its operational status. The parameters to be monitored would be preselected to indicate instrument failure and/or conditions which would result in useless or degraded data being generated. The CRT display provided onboard and/or ground could be used to display the appropriate data upon requests from the experimenter entered through the control keyboard. Periodic checks of this type for equipment malfunctions could either be proceduralized for manual implementation or software programmed for automatic implementation. In either case, response would be to discontinue the collection of scientific data until the equipment problem is corrected.

Benefits Summary

Equipment malfunctions which are allowed to go undetected for extended periods of time dilute the data processing system with unusable data. Skylab EREP experiment S193 gimbal lock and S192 detector failure are examples of this type of equipment problem. Early detection of these types of hardware anomalies results in two major benefits. First, it serves to eliminate expensive processing of useless data, and second, corrective measures are initiated earlier which possibly could result in meaningful data capture not otherwise obtainable. In this manner, the technique could result in eliminating bad data and the acquisition of good data. In view of the fact that new scientific data generating instruments such as the photoheliograph are often very sophisticated and new to the flight environment, the need to monitor that performance in real time is accentuated. This technique should be included in the basic data system design and operational procedures.

OPERATIONAL STATUS MONITOR

- PRESELECTED PARAMETERS FOR FAILURE DETECTION
- AUTOMATED OR MANUAL CONTROL
- ELIMINATE USELESS DATA
- EARLY DETECTION OF NEED FOR REDIRECTION
- ONBOARD OR GROUND MONITOR



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SO-01-S TECHNIQUE NO. 2: ONBOARD NAVIGATION SCHEME

Functional Description

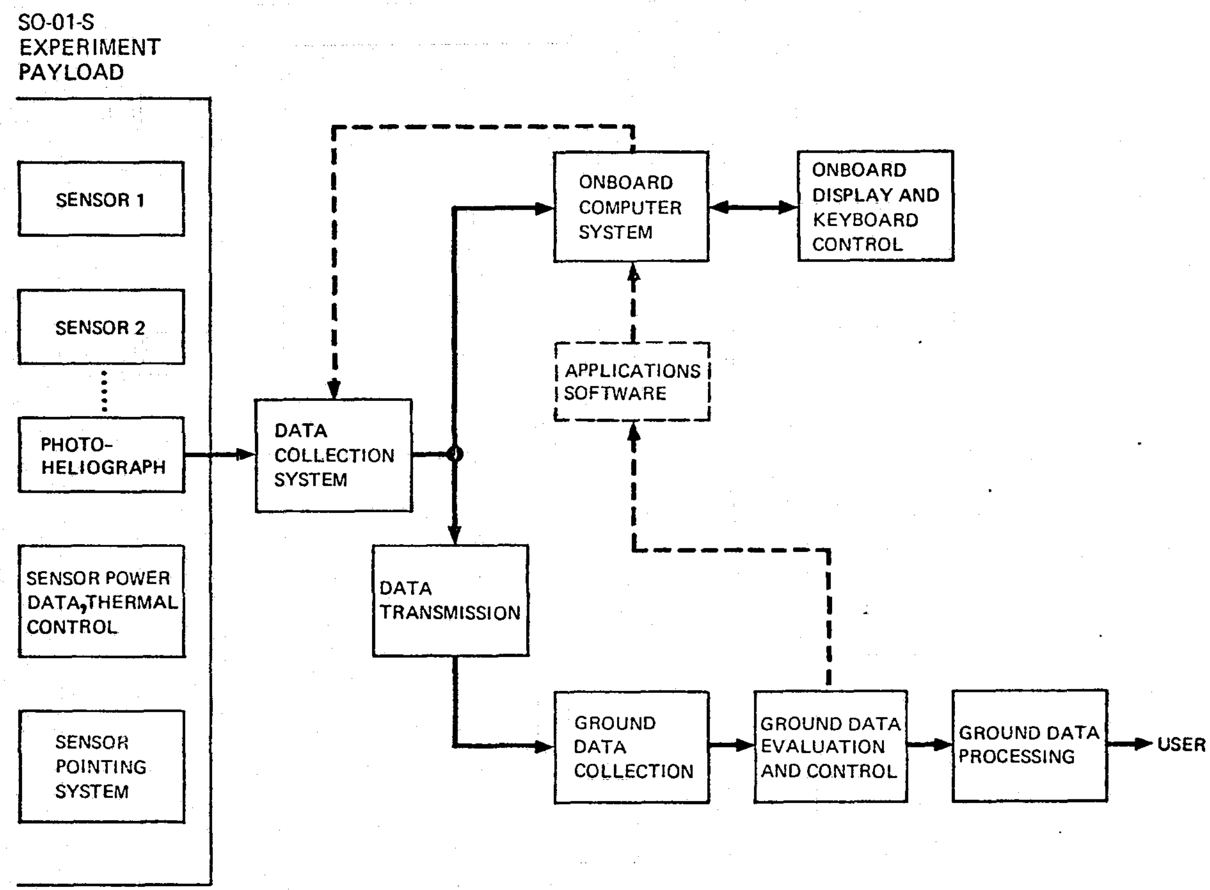
Some of the data from the SO-01-S viewing instruments is seriously degraded if the target of interest is viewed through the earth's atmosphere. A computerized navigation scheme could be programmed to predict when the experiment sensors would be occulted by the atmosphere. A scheme similar to that used for Skylab navigation could be initialized and programmed to use orbital parameters to automatically control the data collection of the affected instruments. Discrete outputs from the software could be configured to effect the automatic control option. Otherwise, caution and warning indications to the crew would be sufficient to support the mantended option. The scheme would require ground support in the form of updates to parameters subject to drift. Data elimination during occultation periods could also be controlled from the ground.

Benefits Summary

Useless and/or degraded data resulting from instruments viewing targets through the atmosphere would be eliminated. This reduces data volume and hence data processing costs. The scheme is versatile in that it could be effected completely automatic or utilizing mantended controls, and should be simple and inexpensive to implement. The navigation scheme developed for the interaction technique would likely be useful for other mission applications which could share development cost responsibility.

ONBOARD NAVIGATION SCHEME

- AVOID ATMOSPHERIC OCCULTATION TO VIEWING INSTRUMENTS
- FEATURES AUTOMATIC CONTROL WITH GROUND UPDATES
- ELIMINATE USELESS AND/OR DEGRADED DATA
- USEFUL FOR OTHER MISSION APPLICATIONS



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SO-01-S TECHNIQUE NO. 3: RADIATION MONITOR

Functional Description

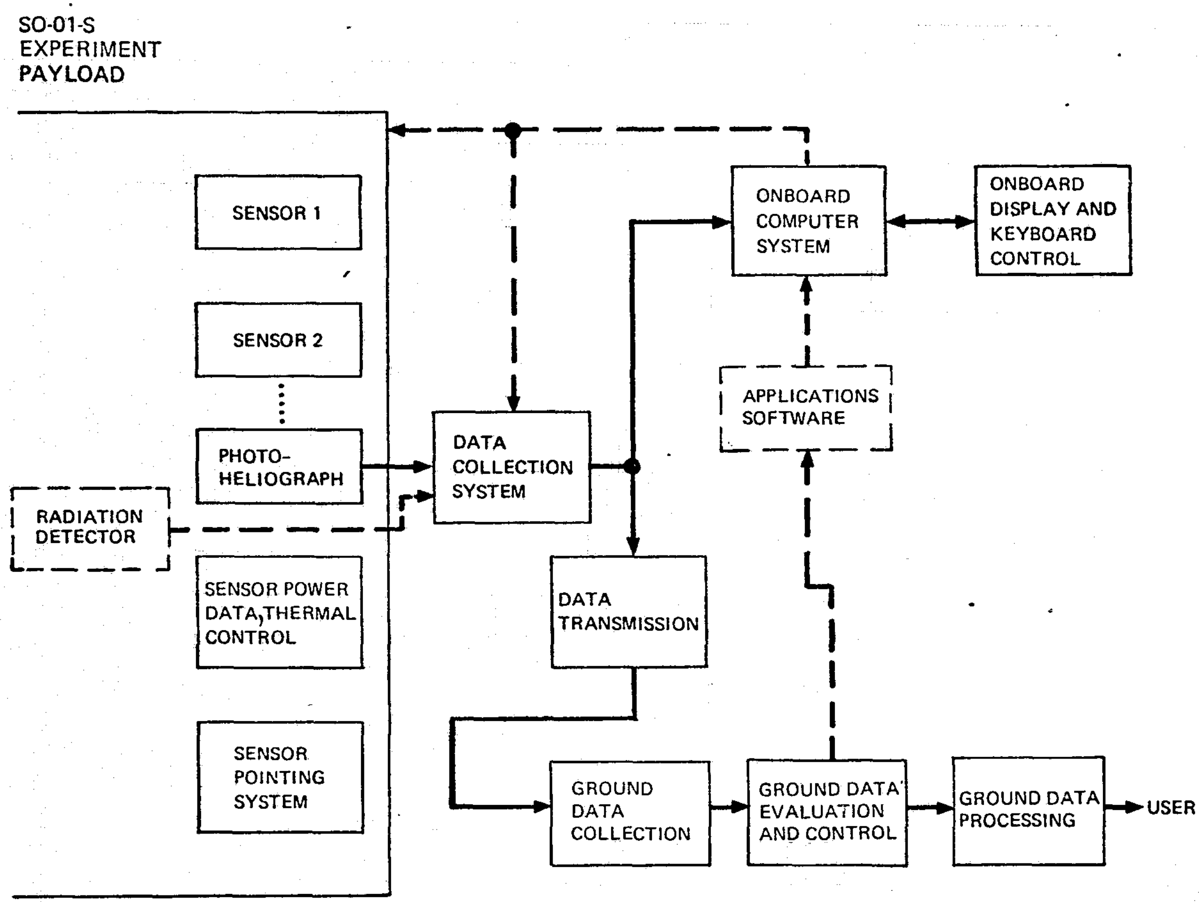
Instruments which generate data in the ultraviolet wavelengths are sensitive to radiation effects. This technique represents a means of eliminating data degraded due to excessive radiation from sources such as atomic explosion residue or the South Atlantic Anomaly. A radiation monitoring element would be added to the experiment complement. When the radiation detector indicated excessive levels, the responsible crewman would react by halting the collection of data in the ultraviolet until the radiation level dropped within acceptable limits. Additional elements required would include the hardware detector, software support and dedicated control and display functions. The support software would involve tolerance levels updatable from the ground or from onboard controls.

Benefits Summary

The cost of processing data rendered useless by excessive radiation is saved with the implementation of this technique. Radiation sensitive elements which might sustain radiation damage can also be protected. Reducing scientific data volume should be a major issue in the design of experiment data systems and this technique is a means toward that end. The scheme appears simple to implement and doesn't introduce complex procedures. Also, the scheme could be managed on-board or ground based. Adjustable limits allow the experiment sponsor flexibility in determining the degree of degradation in acquired data.

RADIATION MONITOR

- ELIMINATE DEGRADED DATA
- UTILIZES UPDATABLE SOFTWARE TOLERANCE TEST
- ADAPTABLE TO SUPPORT PROTECTION OF RADIATION SENSITIVE EQUIPMENT
- RELATIVELY SIMPLE TO IMPLEMENT



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SO-01-S TECHNIQUE NO. 4: SCIENTIFIC DATA MONITOR

Functional Description

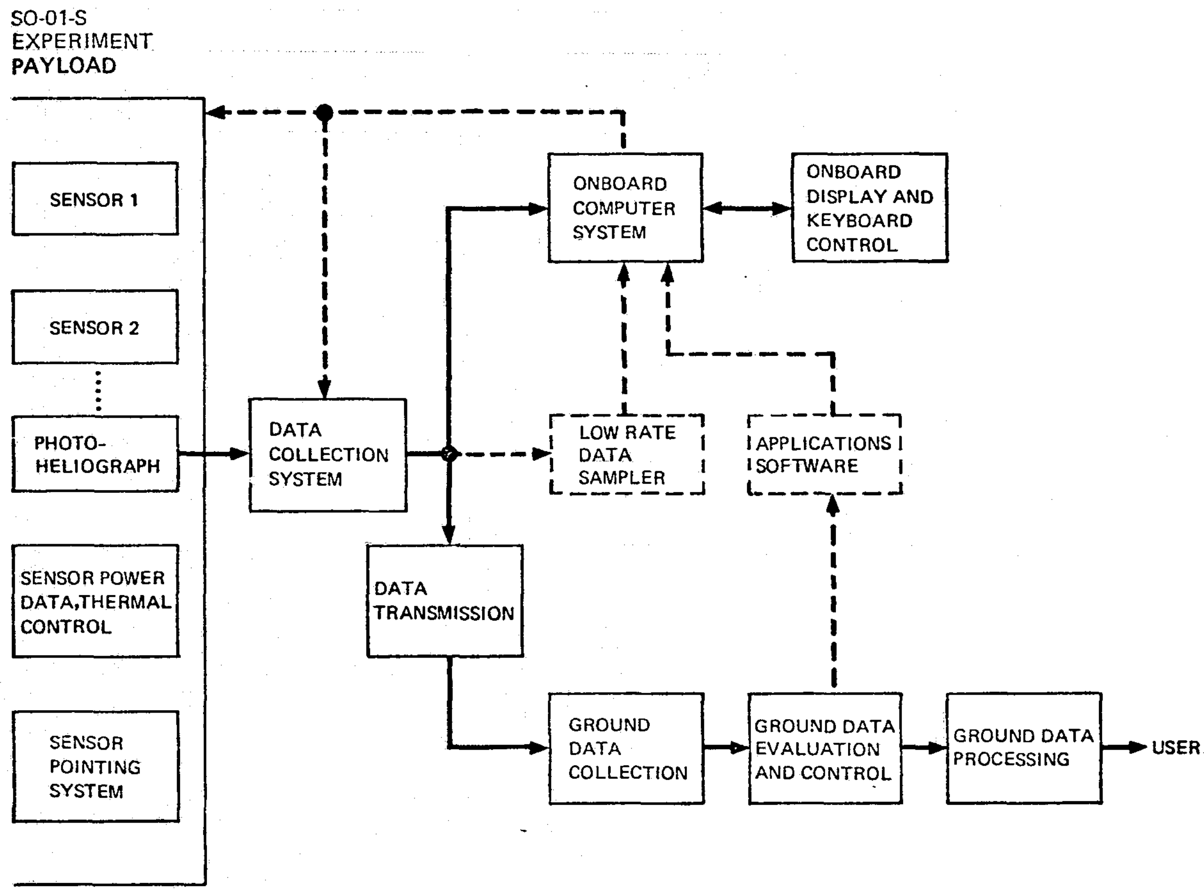
Equipment problems not detected by technique number 1 but which affect the generated data could be detected by monitoring the scientific data. This scheme would also detect problems within the data generation and acquisition subsystems. The scheme is similar in philosophy to technique number 1 in that data is monitored, and a response made interactively to redirect the experiment. However, this technique involves intercepting data from the high rate data transmission lines rather than simply reading operational measurements via the software. Hence, this scheme requires a low rate data sampler to take the required data from the high rate lines and make it available at a predetermined rate to the computer. The software could then perform automatic tolerance checks or simply display appropriate data upon crew request. Response to degraded or useless data would be to redirect or repair the instruments. Control could be enacted from onboard or ground.

Benefits Summary

In addition to early detection of those sensor equipment failures which affect the scientific data, problems with the data generation and collection elements are detectable with this technique. Once these failure conditions are detected, steps can be taken to correct the problem while the data collection is temporarily suspended. This results in data processing cost savings and offers the advantage of early problem correction procedures. This represents a potential for salvaging some success from the mission under these failure conditions. Examples of failures detectable by this procedure were Skylab EREP experiment S192 attenuation switch set incorrectly and failure to remove a lens cover on one of the film cameras. In some cases, data could be eliminated as useless and in other cases data is degraded but usable and could be subjected to predetermined correction procedures. Again, since much "maiden flight" equipment is involved, a real time check of the quality of the scientific data should be included in the mission data management definition.

SCIENTIFIC DATA MONITOR

- LOW RATE SAMPLER REQUIRED
- SOFTWARE TESTS WITH ADJUSTABLE TOLERANCES
- ELIMINATE USELESS DATA
- ADDITIONAL MEANS OF DETECTING EQUIPMENT FAILURE



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SO-01-S TECHNIQUE NO. 5: SOLAR FLARE DETECTION

Functional Description

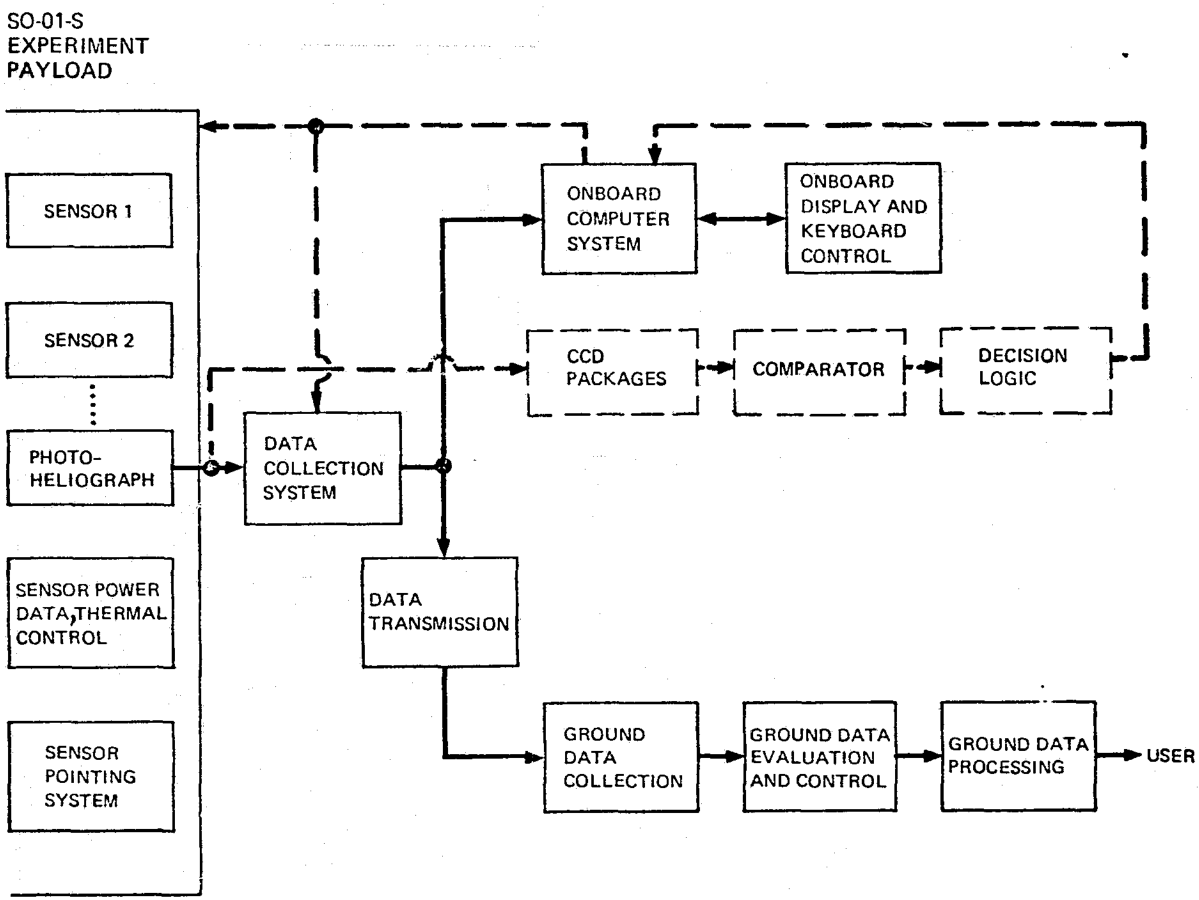
The Charge-Coupled Device (CCD) has been projected as a tool for scientific imaging applications. One such application involves the use of CCDs as image detectors and data storage elements for the prediction and/or detection of solar flares. Since the photoheliograph is concerned with the study of solar flares, this detection scheme could be adapted to the management of photoheliograph data. The instrument data output would be routed to a supporting system consisting of two collections of CCDs, a hardware comparator, a filter, A/D converter, and support software. The system is designed to be flexible and adaptable to predict solar flares based upon data intensity changes or to effect image difference determinations. To detect flares, the system configuration would include two CCD packages, comparator, filter, A/D converter, signal discriminator and decision logic circuitry. For flare prediction, the same elements plus support software would be required. This technique will be designed to detect the flares and indicate to the crew their occurrence. Data retention would begin at the point in time when the system indicated a flare had begun. Otherwise, data would be discarded or transmitted at a lower rate.

Benefits Summary

The potential benefits due to the flexibility of a scheme similar to this is very significant. The solar scientist would be able to direct his experiment with better information benefits and this would result in more optimum data management. Data volume and the associated processing costs would be reduced by eliminating data not directly related to flares or flare type phenomena. The potential scientific information gain is even more significant. Whereas, in the past, scientific data taken for flare study either involved much extraneous data or lacked timely data at flare initiation, the present scheme would facilitate timely and comprehensive data. With the addition of some support software, solar flare prediction is possible which would further increase the benefits realized for flare detection based upon even earlier detection. In still another configuration, the system could be designed to transmit only periodic full images and interim differences, greatly reducing data volume.

SOLAR FLARE DETECTION

- UTILIZES IMAGE DETECTORS
- GENERATES DIFFERENCE IMAGES
- FLARE DETECTION BASED UPON INTENSITY LEVELS
- REDUCE DATA VOLUME
- IMPROVE SCIENTIFIC RETURN FOR MISSION



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SO-01-S TECHNIQUE NO. 6: "WRAP AROUND" RECORDING

Functional Description

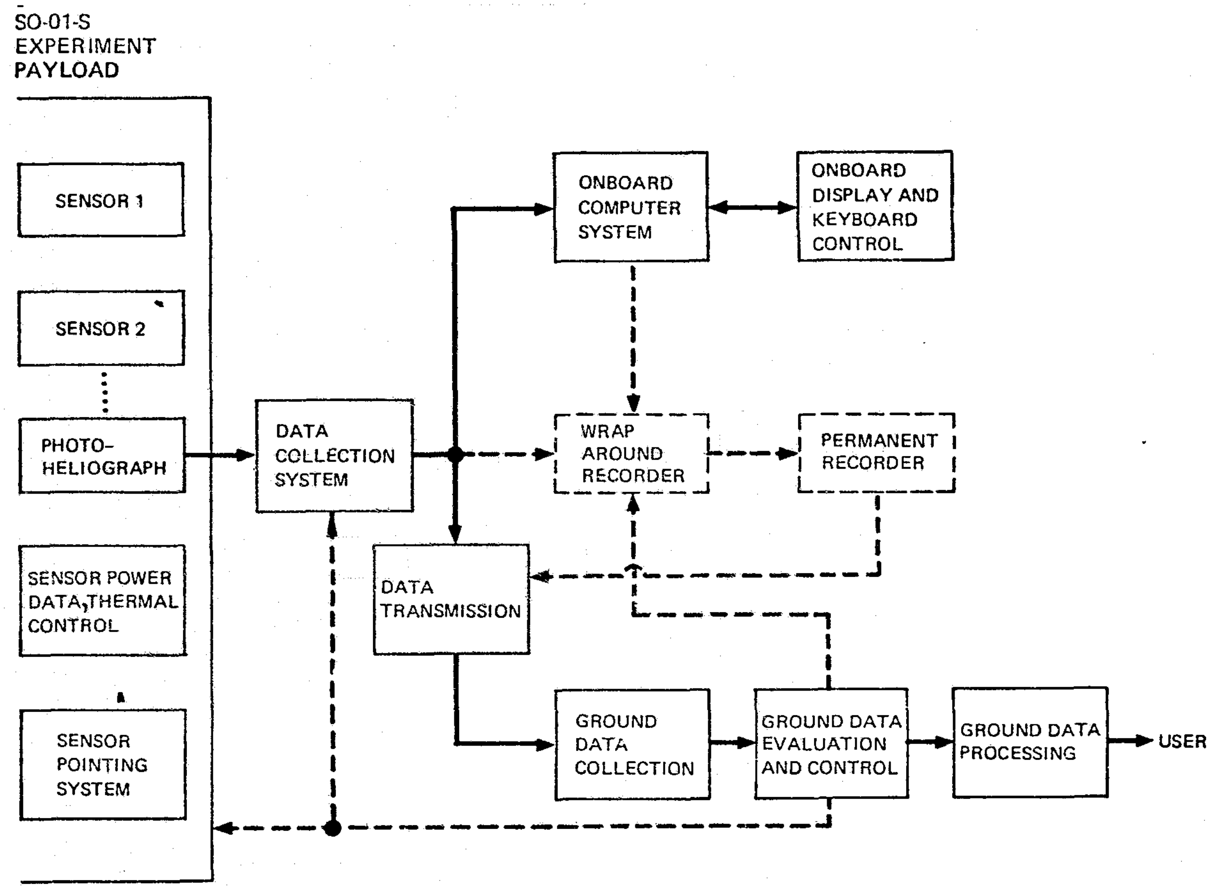
The data collection element of the experiment systems should include a "wrap around" recording capability for limited recording and transmission. The scheme would involve collecting data on a tape recorder and when the end of the tape is reached, data recording would switch to the front of the tape. In this manner, data would be written over previously recorded data in a "wrap around" operation. This scheme has the affect of maintaining a recent history of the scientific data being generated. Whenever a target or phenomenon of interest is detected, the existing data on the recorder would be transferred to permanent storage for return to ground and real time data capture transmission would begin. Once the target of phenomenon "data window" had passed, the data collection scheme would be reduced to the "wrap around" operation. The scheme could be managed either onboard or ground.

Benefits Summary

Implementation of this scheme could result in benefits realized in two areas. The specific benefit resulting will depend upon the present operational characteristics of the experiment. If present practice involves continuous data capture to ensure that the target data is secured, the technique would result in data volume reduction. If the present method involves keeping only that data captured after the target is detected, then the scheme results in significant increase in the scientific value of the data take. This is especially true in the solar physics discipline where the conditions existing just prior to the solar activity phenomenon occurrence are extremely valuable. Proper integration of this technique into the experiment data management scheme could result in a combination benefit of data volume reduction with increased information content. The recorder concept also has high potential for savings if applied to payloads of other scientific disciplines.

"WRAP AROUND" RECORDING

- MAINTAINS RECENT DATA HISTORY
- CAPTURES LEAD IN DATA OF SCIENTIFIC SIGNIFICANCE
- OPTION FOR FULL OR LIMITED TRANSMISSION
- REDUCTION IN DATA VOLUME



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SO-01-S TECHNIQUE NO. 7: DETECTION OF DATA POLLUTANTS

Functional Description

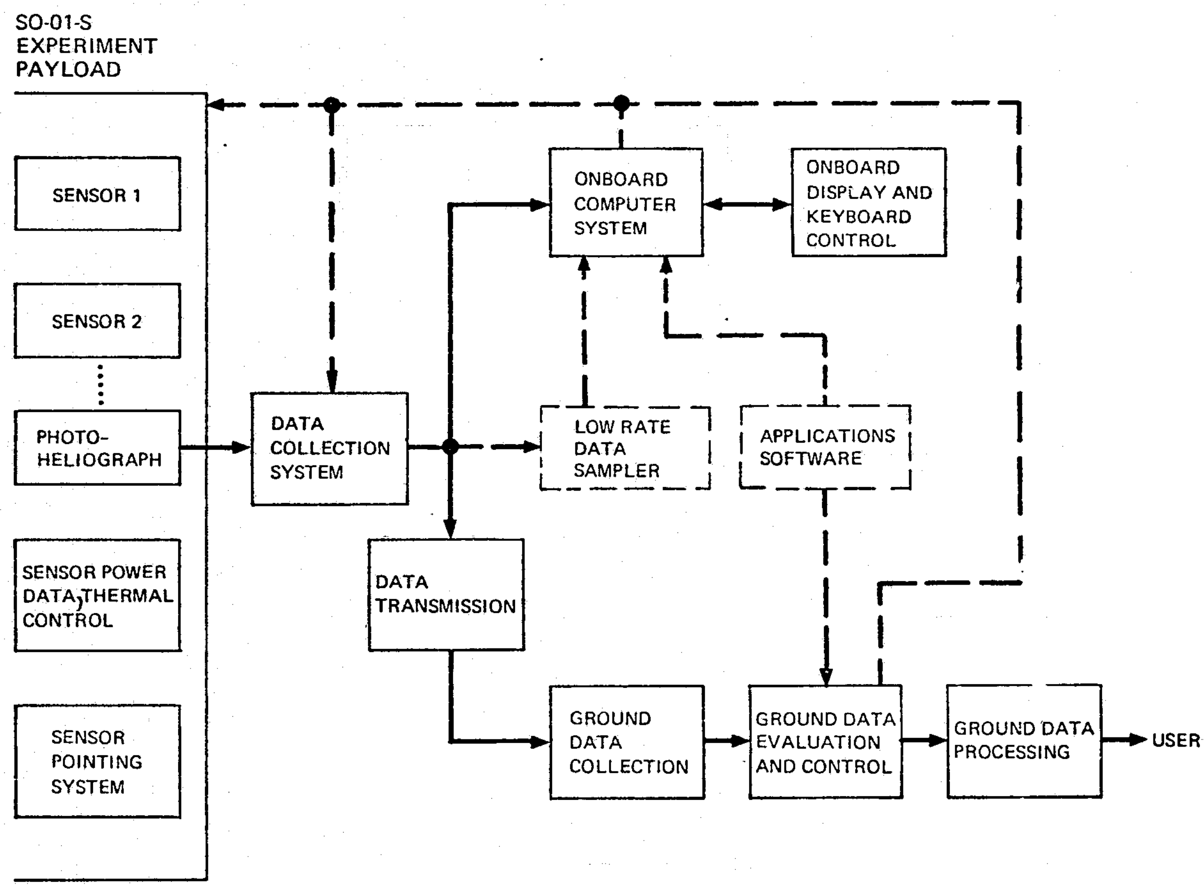
Skylab data reduction experience indicates that the major pollutants of the scientific data are line noise, vehicle control stability, and hardware gimbal jitter. This interactive technique will assume that these pollutants can be detected by hardware and/or software sampling applications and measured by a software procedure. These system induced degradations to the data could be predicted by utilizing onboard observations of the data and software algorithms applied onboard and/or ground. The software algorithms would be designed to use truth tables, standards, fourier transforms, etc. to approximate degradation magnitudes. This capability, coupled with onboard visual display monitoring, could be used to determine needed instrument calibration exercises and/or data reduction adjustments. These experiment instrument and data collection redirections could be effected by ground or onboard personnel.

Benefits Summary

This scheme offers the potential to correct data degradation due to pollutants of the type experienced during the Skylab mission. Some scientific data could be saved that otherwise might be useless, but much more data could be upgraded in scientific value, thereby increasing the information to data ratio. Many of the Skylab people interviewed for this study expressed the need for improved inflight calibration of the instruments. This technique would support those calibration exercises. The scheme would be relatively complex since both onboard and ground support would be actively involved but the potential gain in scientific and perhaps operational information is very significant. Ground based data reduction activities could be refined to generate a better user product.

DETECTION OF DATA POLLUTANTS

- LINE NOISE, CONTROL STABILITY, AND GIMBAL JITTER
- LOW RATE SAMPLER AND SOFTWARE PROCESSING REQUIRED
- DETERMINE NEEDED CALIBRATION AND DATA REDUCTION ADJUSTMENTS
- IMPROVED SCIENTIFIC INFORMATION EXTRACTION



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SO-01-S TECHNIQUE NO. 8: MONITOR SENSOR OUTPUTS

Functional Description

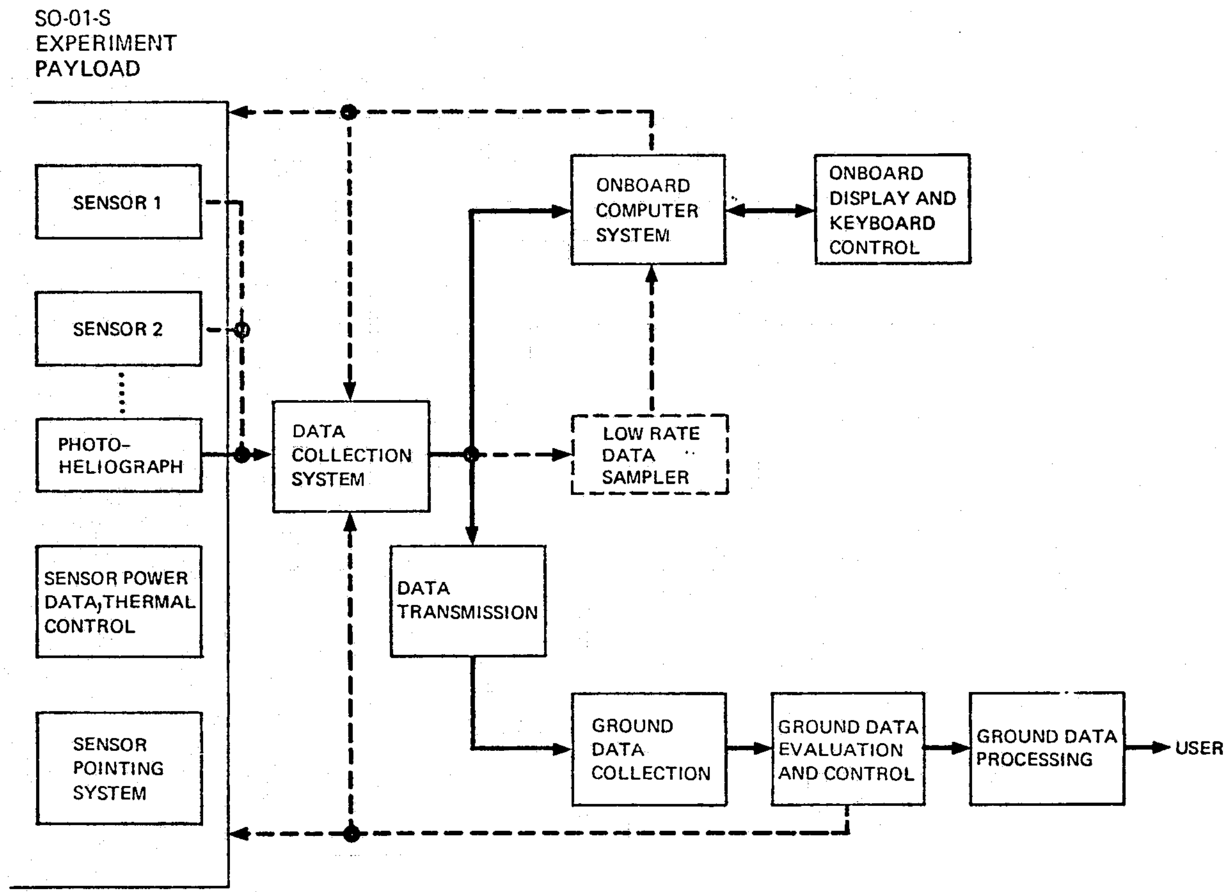
In order to maximize the information to data volume ratio, it is necessary to be extremely selective in the choice of targets to be studied. In many cases, instruments in a payload complement could be used to supplement target selection activities for any member in the group. The outputs of several sensors in the Dedicated Solar Sortie Mission payload could be monitored to indicate the nature of current solar activity for the purpose of pointing the photoheliograph and managing its data production. As an example, the X-ray Burst Detector outputs would indicate present solar energy emission conditions which might affect the desirability of Photoheliograph data. This technique would involve monitoring and processing data from selected sensors in the experiment package and utilizing the results to influence the management of the Photoheliograph. A hardware low rate sampler would be required for those sensors whose data rates exceeded data bus capability. Onboard or ground management of the scheme would be possible. Histogram displays would be a very useful management tool.

Benefits Summary

Application of this scheme offers the advantage of an improved information to data volume ratio. Monitoring solar activity for the purpose of responsively controlling Photoheliograph data takes would result in the capture of data of a higher scientific value. The investigator would have the option of maintaining a constant data volume of greater scientific value (not altering the data take) or reducing the volume of data while retaining similar scientific worth. In this sense, the investigator could choose between reducing data volume or increasing data quality. During periods of high solar activity (as determined from the monitoring scheme) the data rates could be increased and decreased during periods of low activity. If reducing costs became the overriding issue, this technique would offer an optimum method of reducing data volume.

MONITOR SENSOR OUTPUTS

- UTILIZES SENSORS IN THE PAYLOAD COMPLEMENT
- LOW RATE SAMPLER REQUIRED IN SOME CASES
- UTILIZE HISTOGRAM DISPLAYS
- OPTIMIZES TARGET SELECTION
- IMPROVE INFORMATION TO DATA RATIO



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SO-01-S TECHNIQUE NO. 9: DATA RECALL SYSTEM

Functional Description

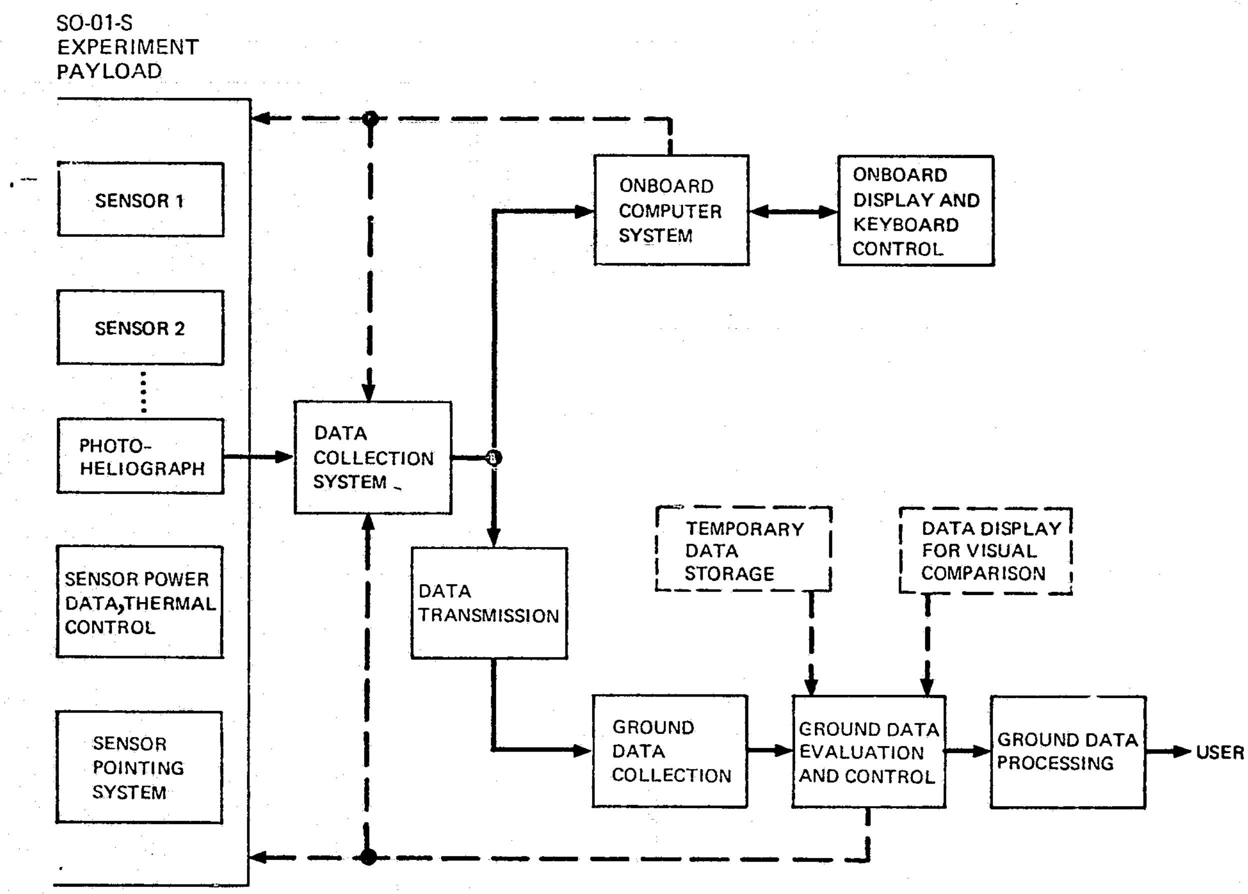
In order to avoid the processing of duplicate data, a comparison scheme could be used to eliminate data which offers no new information content. A data recall system could be used which would involve a storage element to make past data available for comparison to data currently being generated. If duplicate data indications resulted from the comparison, then the present data could be discarded and the generation of data halted until the subject changes to one not previously recorded. This scheme would require computer processing and display for the comparison as well as adequate storage capability. The monitoring element would respond by controlling the data capture and redirection of the experiment. The scheme lends itself best to ground based monitoring but the response to manage the data collection could be enacted either onboard or ground based.

Benefits Summary

The Skylab experimenters interviewed agreed that a significant amount of duplicate data might be eliminated. Targets and phenomenon of interest might represent only a slight change or deviation from a previous data take. With the allocated storage and data recall capability, a cognizant experimenter could monitor the displays to determine if the new data represented a change significant enough to warrant saving. Conceivably, for some experiments, the change detection could be automatically performed by ground software comparing pixel gray levels. In either case, the technique is flexible and the capability would be adaptable to many types of payloads.

DATA RECALL SYSTEM

- REQUIRES STORAGE AND DISPLAY ELEMENTS FOR COMPARISONS
- FACILITATES TARGET IDENTIFICATION
- ELIMINATE DUPLICATE OR REPEAT DATA
- GROUND OPERATION MAXIMIZES USE OF EXISTING FACILITIES
- GROUND OR ONBOARD REDIRECTION OF EXPERIMENTS



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SO-01-S TECHNIQUE NO. 10: CHANGE DETECTION SCHEME

Functional Description

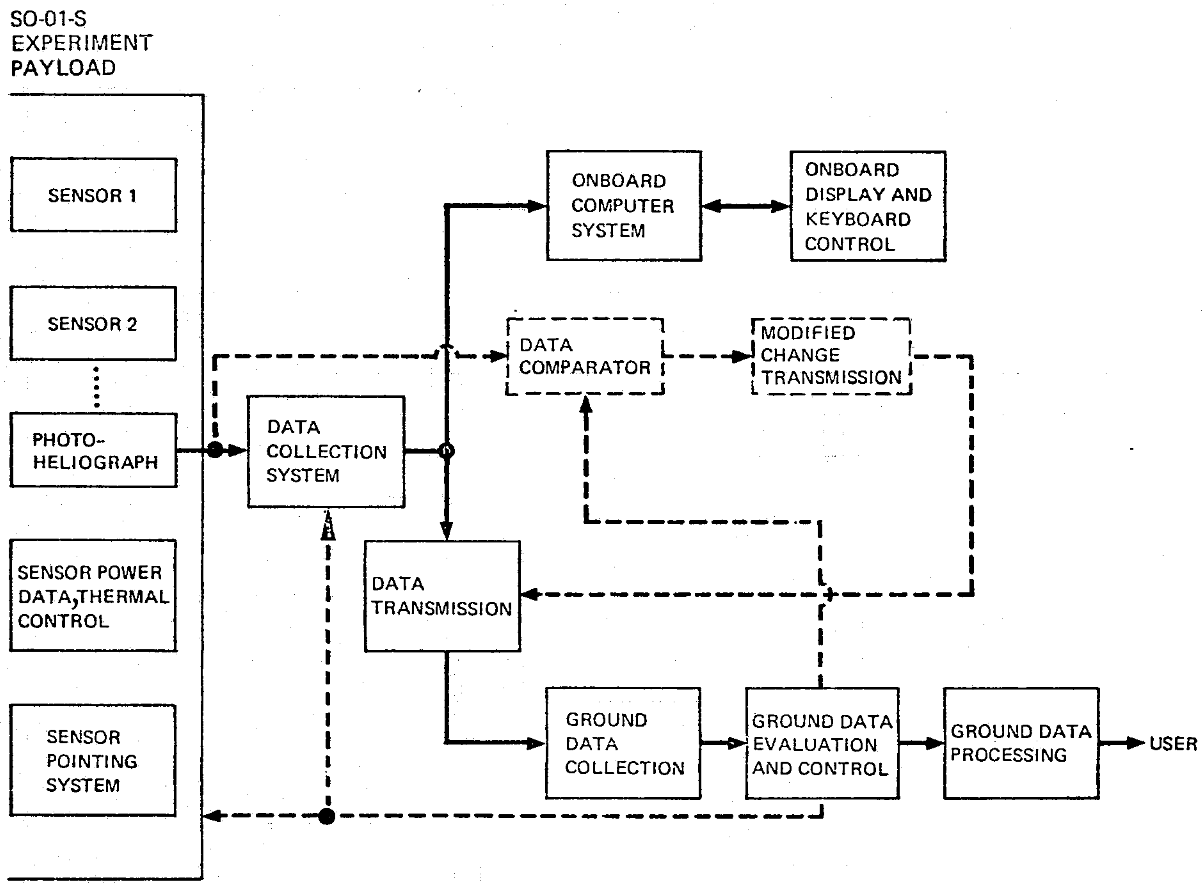
This technique would involve using a change detection scheme in the form of software routines and/or a hardware image comparator to reduce the amount of data collected. Full target images would be collected periodically while in the interim only changes of a predescribed magnitude would be saved. This would eliminate interim data with little or no additional scientific information potential from the data flow. The responsible experiment scientist would determine the magnitude of changes which would be required for retaining the scientific information. The CCD system discussed in Technique No. 5 would be a candidate for implementation of this technique. The scheme would be implemented onboard and managed from the ground. Ground control could activate/deactivate the scheme as an option and adjust the change levels required for transmission.

Benefits Summary

Data volume reduction is the principal benefit associated with this scheme. Very significant reductions can be realized for those experiments whose requirements could be satisfied with changes only above a liberal tolerance. The scheme is general in nature and could be applied to almost any image generating payload. The Solar Physics payloads are particularly suited to benefit from the scheme since usually a single general target with related activity (changes) is under study. The comparator element would probably be a combination hardware/software package applied at either the data collection element or the sensor itself. By including the activation and tolerance level controls in the scheme configuration, the experimenter is given the potential for data processing savings limited only by his individual priorities. Another benefit derived from the change detection system is increased potential for scientific value. In many cases, the extraneous data in a series of full images tend to camouflage the change itself. Since it is these changes (activity borders) that are of the greatest scientific information value, their detection is most important.

CHANGE DETECTION SCHEME

- UTILIZE A HARDWARE/SOFTWARE IMAGE COMPARATOR
- PERIODIC FULL IMAGES WITH INTERIM CHANGES
- ALTERABLE CHANGE LEVELS
- DATA VOLUME REDUCTION
- INCREASE SCIENTIFIC VALUE POTENTIAL



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SO-01-S TECHNIQUE NO. 11: SOFTWARE DATA EDITING

Functional Description

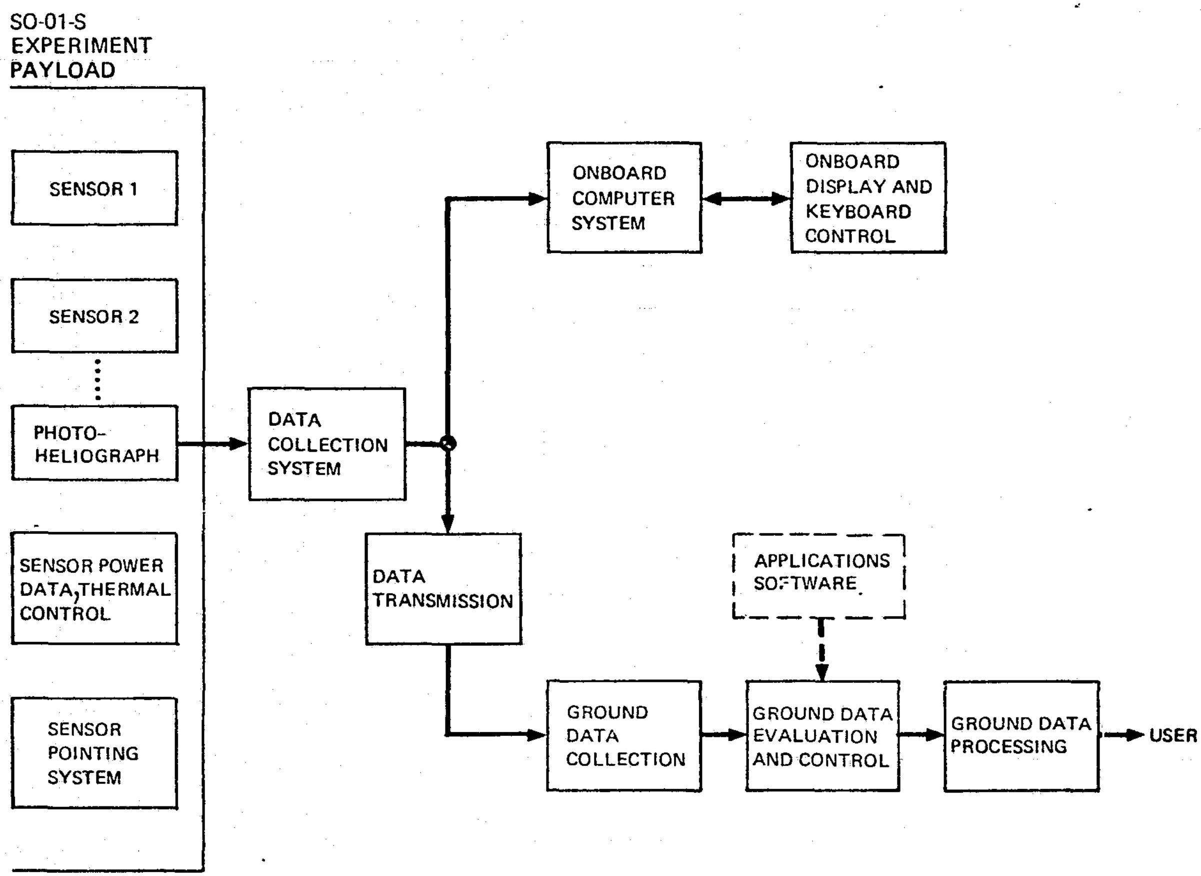
This technique would involve initial processing of the scientific data via additional ground software. The software routines would be designed to eliminate data which can be identified as unusable. Examples of this type of data might be "all zero" or "all one" data, instrument saturation data, out-of-tolerance data, etc. The experiment sponsors could identify those characteristics of data generated by their sensors which would be unusable. From this, software tests could be written for first application once the transmitted data reaches the ground. This first step in the ground data processing network would reduce the volume of data to be processed further.

Benefits Summary

The data discriminator would reduce the volume of data subjected to normal ground processing and specialized user related processing. Some experimenters indicated that as much as a 10:1 reduction in the data to be further processed might be eliminated by such a scheme. This reduction in data processing costs would also be accompanied by an increase in the scientific value potential. By eliminating the pollulants at the initial processing step, the less sophisticated user processing systems would probably be more effective in extracting the scientific information.

SOFTWARE DATA EDITING

- GROUND BASED SOFTWARE ALGORITHMS
- ELIMINATES CERTAIN CLASSES OF INVALID DATA
- SAVES DATA PROCESSING COSTS
- NEGOTIATED WITH EXPERIMENT SPONSORS
- IMPROVED USER PRODUCTS



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SO-01-S TECHNIQUE NO. 12: PLANNED DATA RATE REDUCTIONS

Functional Description

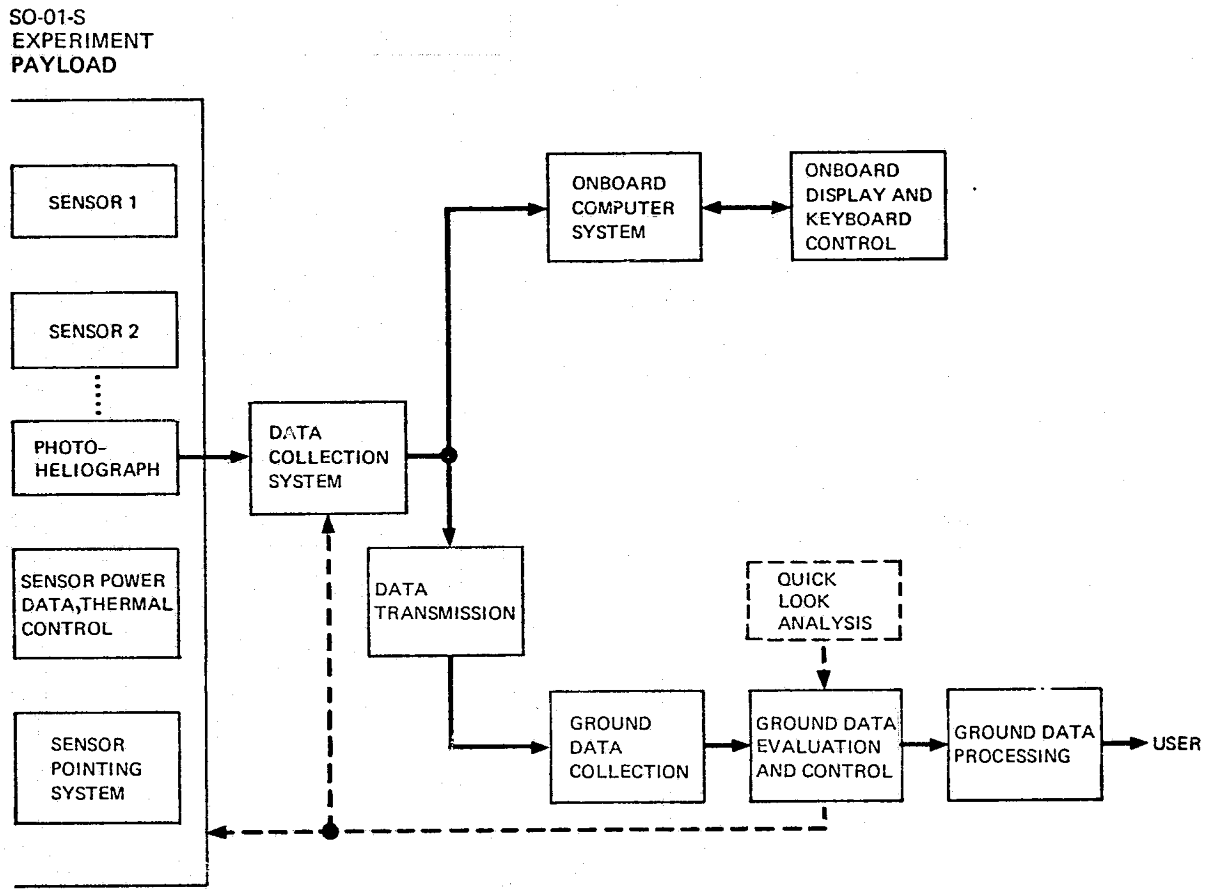
Several of the scientists contacted for this study expressed the opinion that high data rates would be desirable in the early stages of a mission. However, they felt that once confidence was established in the data system, then perhaps lower data rates would be acceptable. The magnitude of the data reduction and the point in time at which it is effected would have to be negotiated with the experiment principal investigators. Functionally, the technique will involve an onboard or ground based interactive element effecting the data reduction by reducing the data generation rate or reducing the data sample time.

Benefits Summary

This technique offers the single advantage of data volume reduction. The potential reduction magnitude is very significant depending upon experimenter demands. Scheme implementation appears very simple and inexpensive, and its procedural nature would be adaptable to any payload.

PLANNED DATA RATE REDUCTIONS

- REDUCTION TIME A FUNCTION OF DATA SYSTEM CONFIDENCE
- TIME AND MAGNITUDE NEGOTIATED WITH PIs
- DATA VOLUME REDUCTION
- ONBOARD OR GROUND BASED CONTROL



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SO-01-S TECHNIQUE NO. 13: FIELD OF VIEW MONITOR

Functional Description

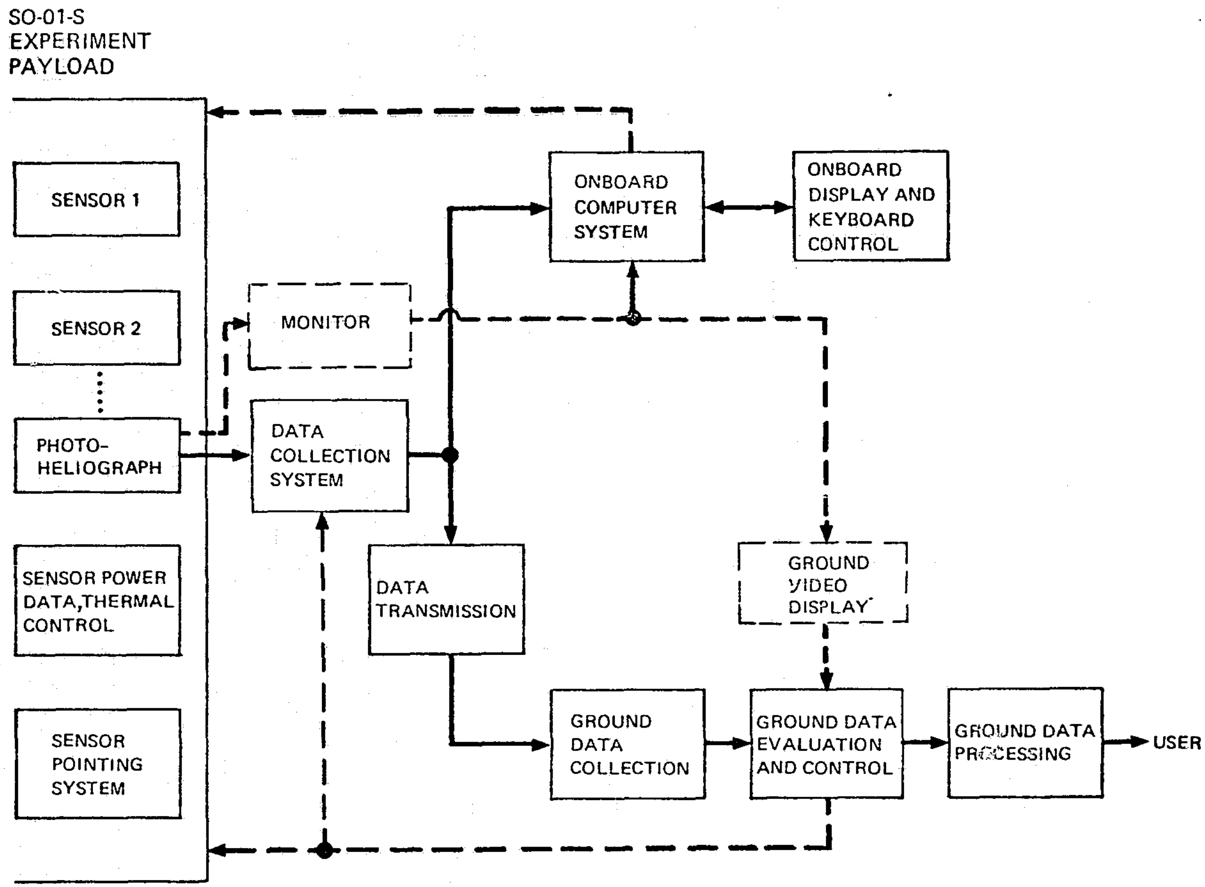
Optimum collection of scientific data requires proper target selection and accurate instrument pointing. To facilitate these requirements, some experiments must be accompanied by a monitoring device. The monitor would be slaved to the pointed sensor and would provide for both onboard and ground visibility for maximum data selectivity. The video output from the monitor would be displayed on onboard and ground CRTs and responses to control the data collection could originate at either control keyboard.

Benefits Summary

The extended target visibility offered by this technique optimizes the associated data collection. Benefits might be in data volume reduction or scientific information increase. Some extraneous data might be eliminated and or data of a higher information content might be collected due to the improved pointing and target selection. The extended visibility quality enables more scientific epertise to be factored into the data management exercises. Instruments should be equipped with monitors designed for the same wavelengths in which the sensor generates data. This would provide visibility in the wavelengths viewed by the experiment sensors while a separate monitor could be included to assure provision of the visible wavelengths. This scheme of monitoring in the wavelength in which the data is generated was recommended by several of the Skylab scientists interviewed.

FIELD OF VIEW OF MONITOR

- MONITORING INSTRUMENT SLAVED TO SENSOR
- ONBOARD AND GROUND VISIBILITY
- VIEW IN SENSOR WAVELENGTHS
- IMPROVED POINTING AND TARGET SELECTION



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EO-06-S PAYLOAD CONSIDERATIONS AND BLOCK FLOW DIAGRAM

The information narrative appearing on this page supports the two successive charts immediately following. The first paragraph is applicable to the chart appearing on page 54A and subsequent paragraphs refer to the chart on facing page 55.

Several specific considerations influenced the development of the techniques for interaction that were applied to EO-06-S. They are as follows: the baseline data flow is derived from the Level B sheets; the onboard computer referenced in Level B is assumed to be part of CDMS; specific software application requirements may be shown separately for illustration as an interaction processor; and ground interaction techniques for EO-06-S are the same in principle as those presented for SO-01-S. SO-01-S ground based interaction techniques which apply to EO-06-S are: Operational Status Monitor, Scientific Data Monitor, Data Recall System, Software Data Editing, Planned Data Reduction and Field-of-View Monitoring.

EO-06-S is an Earth observation mission with the objective of collecting high resolution multispectral data for use in Earth resource mapping of land masses with the view to aiding resource detection, identification, location and measurement.

The mission is singularly devoted to the pallet mounted, 7 spectral band, oscillating scan multispectral scanner (MSS). The MSS consists of a spectrometer assembly, the sensor, and the spectrometer data handler (which may be included as a part of the spectrometer assembly).

At the present level of specification, the MSS will have on-orbit control only via onboard MSS associated displays and controls mounted within the Spacelab.

The expected number of Sortie flights is 17 (1980 - 1991) with a nominal flight duration of seven days. Experiment observation time is .25 Hr/Hr @ 6 times/day (or 30 times per 7-day mission).

All digital data will be produced by the MSS. It is to be stored in a wideband tape recorder which is housed in the experiment pressurized area. Data storage will require 4 reels of tape per day (at the present time no data is to be transmitted to ground except that returned on the tapes). Data is specified at up to 78 MBS (informally at up to 240 MBS with 2.7×10^{12} bits total per mission).

EO-06-S CONSIDERATIONS

- BASELINE DATA FLOW FROM LEVEL B
- 'ONBOARD COMPUTER' SHOWN ASSUMED PART OF CDMS
- INTERACTION PROCESSORS SHOWN SEPARATE FOR ILLUSTRATION
- GROUND TECHNIQUES SAME AS SO-01-S IN PRINCIPLE
  - OPERATIONAL STATUS MONITOR
  - SCIENTIFIC DATA MONITOR
  - DATA RECALL SYSTEM
  - SOFTWARE DATA EDITING
  - PLANNED DATA RATE REDUCTIONS
  - FIELD OF VIEW MONITOR

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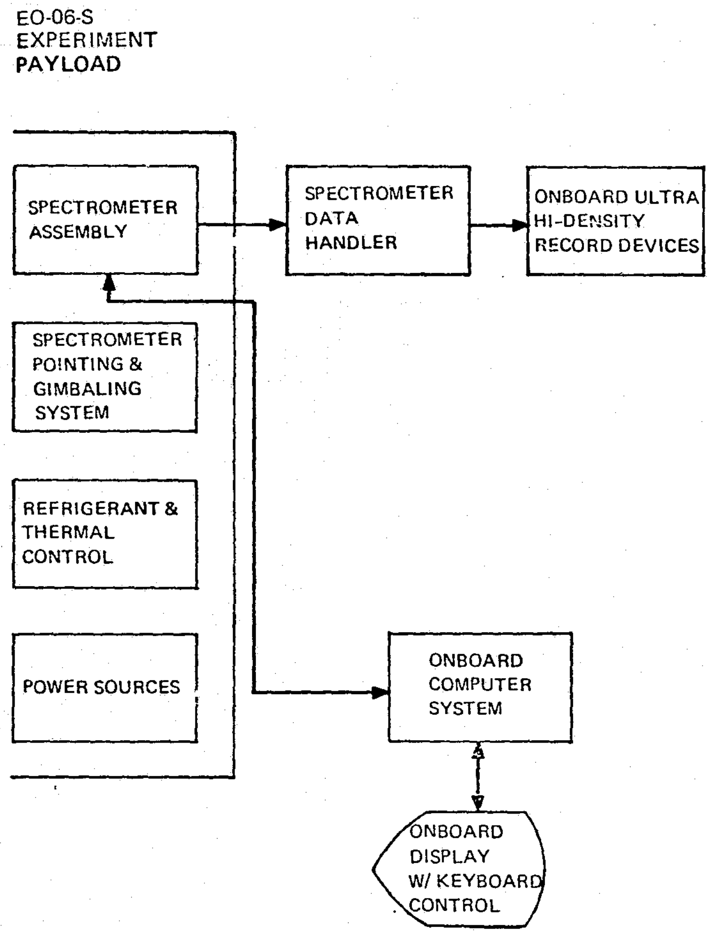
EO-06-S PAYLOAD BLOCK FLOW DIAGRAM

- HI-RESOLUTION MULTISPECTRAL DATA OF LAND MASSES
- OSCILLATING SCAN MSS
- ON-ORBIT CONTROL ONLY/NOM. 7 DAY MISSION
- NO DATA TRANSMITTED TO GROUND/NO GROUND TIMING UPDATES/NO TV/NO DUMPS
- $\approx 2.7 \times 10^{12}$ BITS DIGITAL RETURNED VIA $\approx$27 REELS MAG. TAPE



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EO-06-S TECHNIQUE NO. 1: IMPROVED PAYLOAD MANAGEMENT IN THE NON-VISIBLE SPECTRUMS

Functional Description

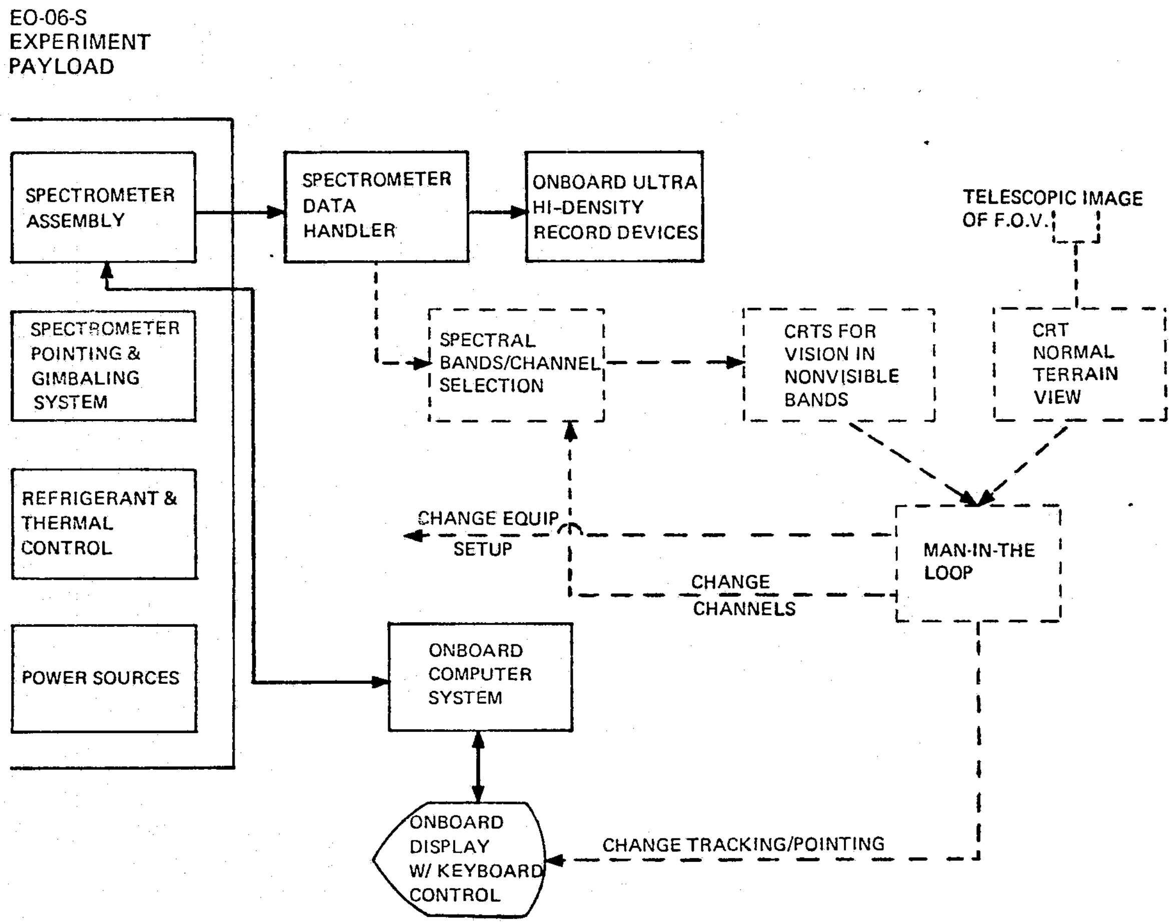
This technique provides for a televised, telescopic (with cross-hair) viewing of the terrain being targeted for observation by the Multi-Spectral Scanner (MSS). Correspondingly, provision is made for additional CRTs such that 2 or 3 spectral bands of the MSS may be viewed in conjunction with the view of the terrain. All of the spectral bands would be selectable for viewing.

Benefits Summary

Enhancement of the visual capabilities of the interested experiment operator who is scientifically/technically trained can result in elimination of as much as 80% of the data ordinarily collected. [This is one of the most conservative estimates obtained from experienced principal investigators (P.I.)]. An 80% reduction in data or a 5:1 compression in the recorded (or telemetered) raw data is viewed as significant. Additional considerations might include the fact that CRT 'eyes' may be generalized to include applications to other payload disciplines such as Solar Physics (XUV monitor, WLC monitor, H-Alpha, etc.).

IMPROVED PAYLOAD MANAGEMENT IN THE NON-VISIBLE SPECTRUMS

- ACQUIRE TARGET IN VISIBLE SPECTRUM
- PROVIDES 'EYES' TO 'SEE' IN SPECTRAL BANDS NOT VISIBLE OR A SUBSET OF THE VISIBLE
- PRELIMINARY FUNCTIONAL CHECKS
- OBSERVE OPERATOR ACTIONS



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EO-06-S TECHNIQUE NO. 2: PROCESSOR FOR USE OF SAMPLING TECHNIQUES

Functional Description

This technique will provide hardware that will accommodate the use of simple data sampling schemes. Such schemes could include threshold, limit or tolerance testing of pixel brightness values on a per pixel basis, per area of frame basis or on a full frame basis. Hardware to accommodate such sampling schemes would include buffers sufficient in size to hold a 'frame' of data and a 'number crunching' mini-computer to perform vast quantities of simple calculations in very rapid fashion. Only the data passing the sampling criteria would be recorded. The display would provide the operator with a means to sample the samples to confirm processor performance.

The sampling should be automated for a given flight except for minor software adjustments that might be considered in real time. It is not a technique amenable to manual operation except possibly a manual initiation and termination of sampling time.

Benefits Summary

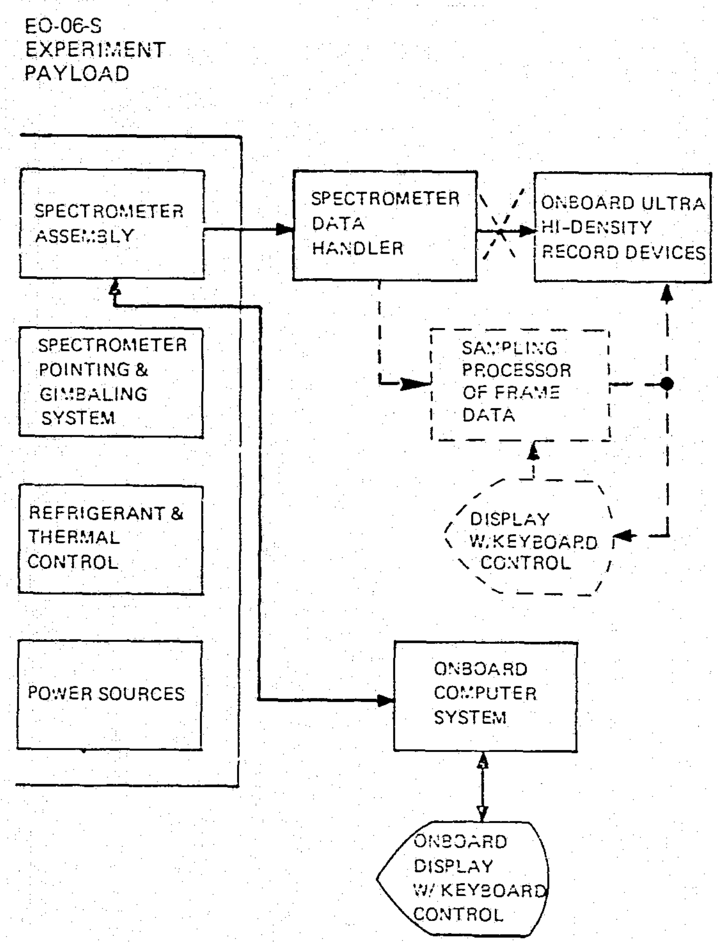
Savings will be realized by the culling of data of undesirable spectral density (such as data with cloud cover, saturation of calibration sources and electronics, etc.), and data that does not otherwise satisfy a spectral requirement such as a spectral threshold. Reduced quantities of data will save in ground storage and processing costs and evaluation time.

Recording consumables could be conserved to require less tape per flight or to extend flight duration or the data take durations.

Savings will be realized by requiring data needs to be defined prior to flight. Foresight and planning to define data bandwidths expressly needed and to obtain test parameters for the sampling scheme would be expected to filter into time lines, backup data takes and/or flights, etc.

PROCESSOR FOR USE OF SAMPLING TECHNIQUES

- SCREEN UNDESIRABLE DATA (HAZE, CLOUDS, ETC.)
- SAVE DESIRABLE SPECTRAL COMBINATIONS
- SAVE DESIRABLE SPECTRAL BOUNDS
- PROCESSOR FOR 'CHANGES ONLY' SAMPLING



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EO-06-S TECHNIQUE NO. 3: 'QUICK LOOKING' DATA FOR SYSTEM PERFORMANCE

Functional Description

This technique provides for that minimum of onboard real time data processing that is sufficient to yield gross indication of data quality and instrument performance, i.e., "Quick Look" periodically enough scientific data to assure continuing engineering performance. The scheme would be automated to the extent that processing would involve computerized processing but could entail manual initiation/termination and possibly 'Smart' terminal (keyboard' CRT & disk memory) control. Decision making as to data quality would most likely be based on the subjective analysis by the experimenter of a processed 'frame' as displayed on the CRT. Some decision making might be in accordance with 'yes' or 'no' attribute sampling obtained from computerized test criteria.

Benefits Summary

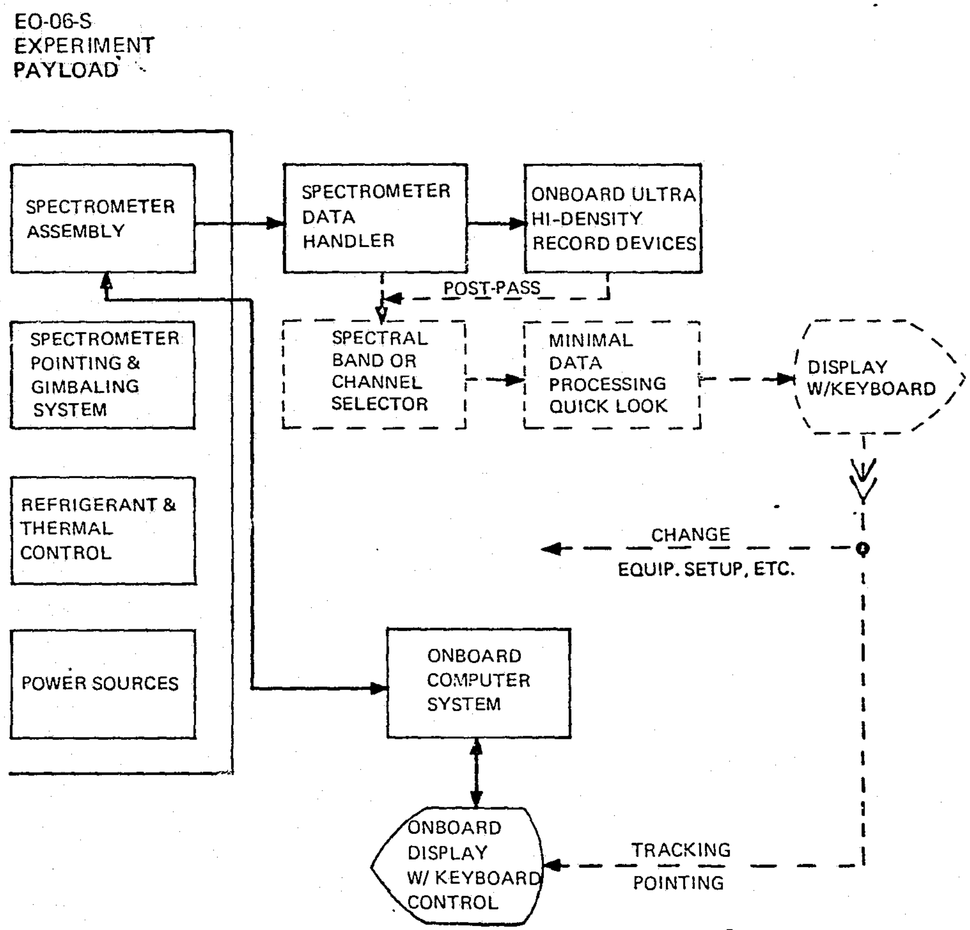
The best possible lead time will be provided to correct data collection problems (for example - change experiment set up, perhaps adjust a filter network, attenuation setting, etc.) and either salvage or reschedule the data take.

Conceivably, the payload and hardware development cycle of the early flights may justify such an Interaction Technique as this on the basis that payload degradation could be so severe as to cancel the remainder of the mission. This would otherwise be unknown until the ground processed the data tapes.

Data savings are not fully quantifiable though it is known that for Skylab - attenuations were on occasions set incorrectly, that calibration sources degraded and that electrical noise alone nearly destroyed the data. Extensive computerized ground processing has been and continues to be necessary to salvage that data. Verifying data integrity and equipment set up as the data take progresses would preclude almost all of the corrective processing of the nature described for Skylab data.

'QUICK LOOKING' DATA FOR SYSTEM PERFORMANCE

- CONFIDENCE IN DATA QUALITY
- TIMELY EXPERIMENT RE-DIRECTION
- EFFICIENT USE OF CONSUMABLES
- UTILIZES BUILDING BLOCKS



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EO-06-S TECHNIQUE NO. 4: SYSTEM ANOMALY DETECTION PROCESSOR

Functional Description

This technique would provide a software system capable of detecting and flagging major system anomalies. The software system would be configured to dump all pertinent information that would indirectly aid to reconstruct (correct and/or salvage) experiment data. Flags could be set showing a 'checklist complete' for correct set up of equipment, calibration checks performed satisfactorily, equipment in standby (fully warned up) or equipment in operation. Anomalies of concern might include vehicle control, MSS thermal stability or MSS gimbaling, etc. Flags might be displayed and recorded within the scientific data stream.

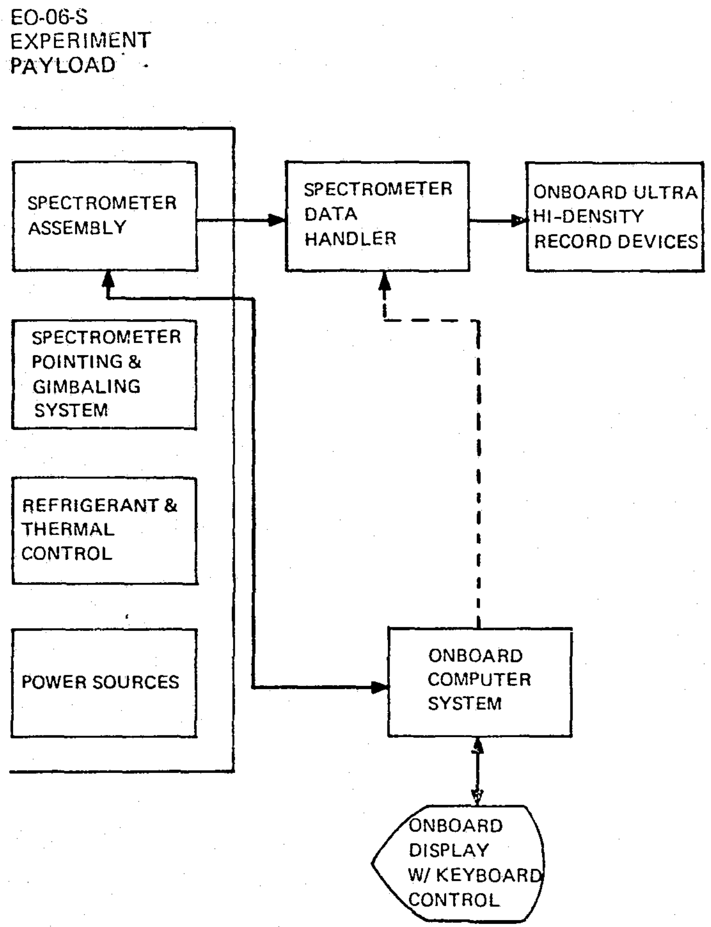
Benefits Summary

Events can be fixed in time by flags so as to bound the nature and magnitude of problems when they occur as well as where (axis, part or data process step). Anomalous events can be noted when they occur for possible corrective action in near real time especially in MSS hardware.

Many problems which might occur could then be minimized by having the appropriate corrective data. For example, key data words might be expanded to telemeter greater accuracy (i.e., go from 12-bit word to 16-bit word). Intermediate terms (selected in advance) in a single precision or double precision series of calculations might be telemetered. Internal (to the software programming) status words might be dumped into the data stream. Savings would be in that area of corrective data processing required when major system problems do occur and experiment data is degraded. That is, vehicle control would be monitored and major problems with accompanying significant information would be immediately indicated in the scientific data (the only thing needed in this case might be to merge the telemetered vehicle control data with the experiment data so that corrective processing of experiment data could be performed).

SYSTEM ANOMALY DETECTION PROCESSOR

- FLAGS SYSTEM ANOMALIES
- MERGE EVENTS WITH SCIENTIFIC DATA
- MERGE DATA SELECTABLE
- EXPEDITES GROUND PROCESSING



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EO-06-S TECHNIQUE NO. 5: 'QUICK LOOK' SCREEN FOR THE 'FRAME OF INTEREST'

Functional Description

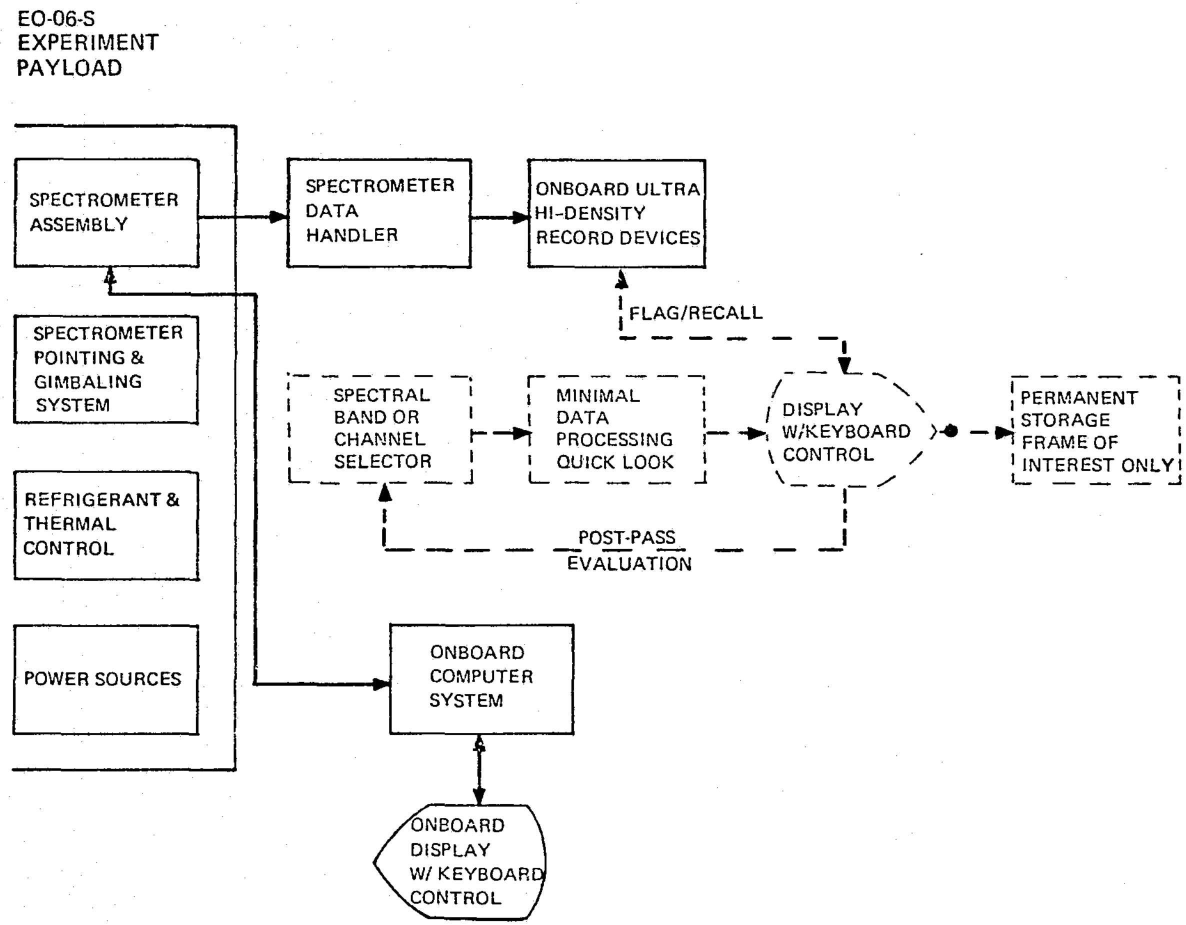
Given a minimum of onboard real time data processing capability, this technique provides means to flag (manually using, say, a keyboard) and to subsequently recall for a configuration examination data that is of signfiicant interest. The technique would be applied to an intermediate storage recall (rather than permanent storage or data to be telemetered by delayed transmission). Data found to be of significant interest could be permanently stored -- otherwise, it could be deleted. The technique as envisioned involves man-in-the-loop use of software techniques to recall, display and screen data to find that which satisfies mission objectives.

Benefits Summary

Savings are realized by the benefit of verifying data of interest and culling all of that of no scientific value, which is possible with data recall capability. Savings can also be realized by the opportunity to visually apply quality checks to the data when it is recalled providing opportunity to perform remedial action to correct MSS operation or to make new or additional data passes over a target.

'QUICK LOOK' SCREEN FOR THE 'FRAME OF INTEREST'

- SAVE DATA OF PRIMARY INTEREST
- NOTE TARGETS OF INTEREST
- DATA TAKE ASSESSMENT -- RETAKE? RE-DIRECT? CANCEL?
- REDUCE ONBOARD DATA STORAGE



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EO-06-S TECHNIQUE NO. 6: POST PASS, CRITICAL ANALYSIS SCREEN FOR SCIENTIFIC CONTENT

Functional Description

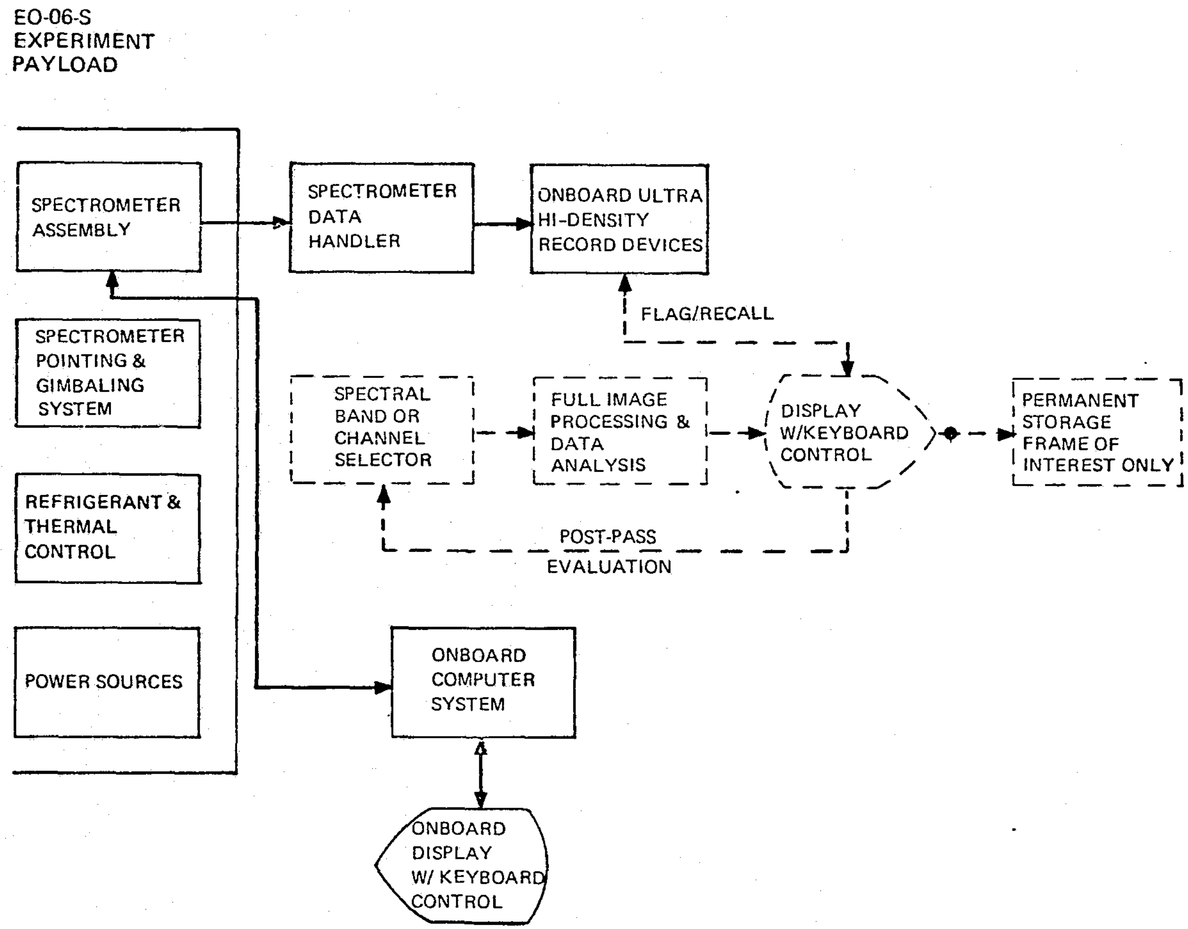
EO-06-S Multi-Spectral scanner digital data is not expected to be telemetered to the ground due both to high data rate and large volume of data. As the need for more precise information increases and as the flights evolve towards longer missions (7 days extended to 30 days or more) the delay in critical assessment of how well data gathering objectives have been met perhaps will not be acceptable (the value of Multi-Spectral scanning data will in almost all cases be determined by the 'freshness' of the data, i.e. action required immediately for disease infested crops in fruit production cycle). This technique, therefore, will extend the minimum onboard real time data processing and selective data recall capability to include the full complement of onboard image data reduction capability that will permit post pass critical analysis of data. This technique follows as the logically expected extension of EO-06-S Techniques 3 and 5 as needs become more specific and as the state-of-the-art grows in spectral signature analysis, etc. Benefits are foreseen because of the value of in-depth scientific knowledge that is useful in technical consultation with the ground about observations and how well data gathering objectives have been met. Technical decision making may be realizable about a data retake or the redirection or cancelling of scheduled data taken on a near real time basis.

Benefits Summary

Savings involving this technique fall into the category of: 1) looking for specific information and an early satisfaction of the requirement (i.e., confirm value of data taken in flight. This may save a retake on next orbit or even a reflight by requiring a retake on the next orbit), and 2) obtaining scientific content form various parts of image reduction and conveying that information to a user while the information is 'fresh'.

POST PASS, CRITICAL ANALYSIS SCREEN FOR SCIENTIFIC CONTENT

- EXTENSION OF QUICK LOOK SCREEN FOR 'FRAME OF INTEREST'
- TOTAL DATA TAKE ASSESSMENT
- REDUCE ONBOARD DATA STORAGE



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EO-06-S TECHNIQUE NO. 7: A SCREEN TO RECORD ONLY WHEN CONDITION REQUIREMENTS ARE MET

Functional Description

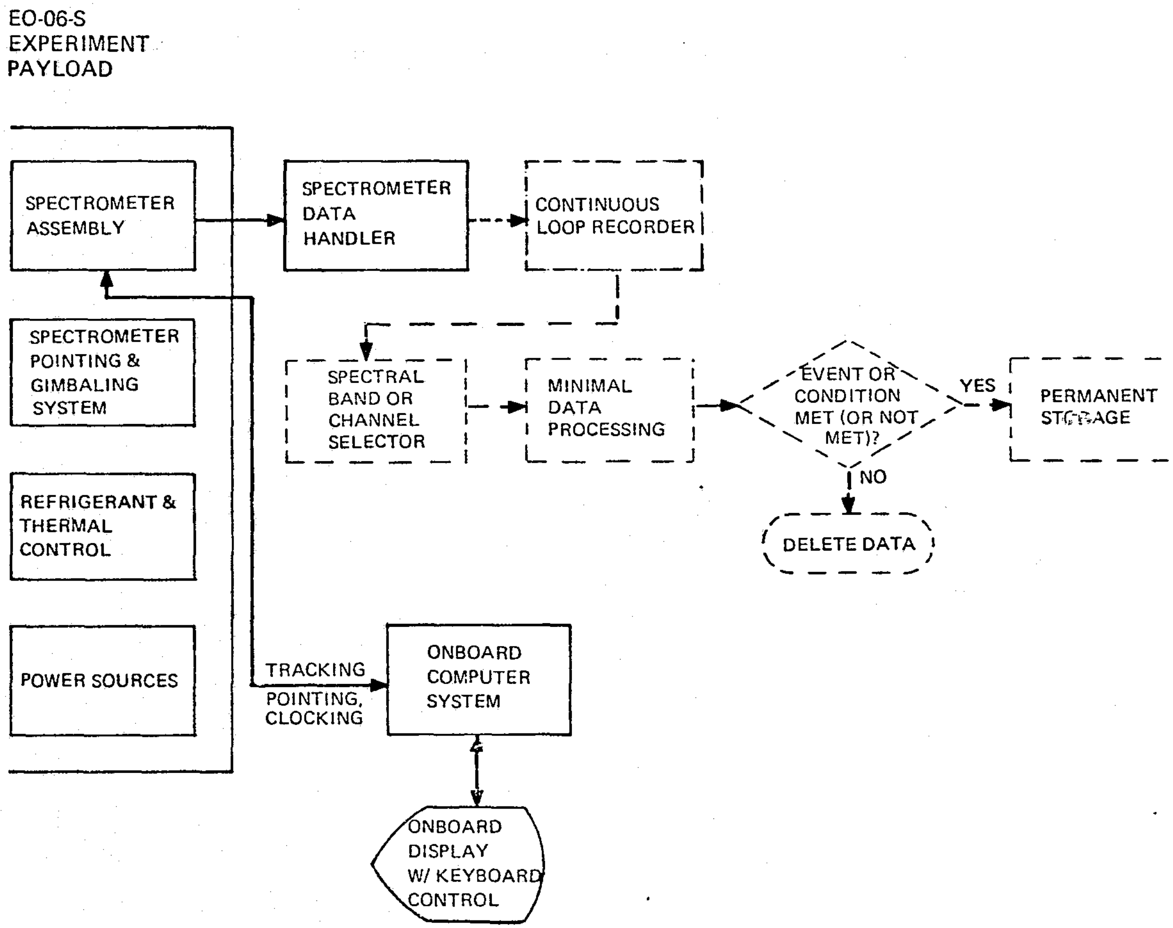
This technique would provide detectors capable of sensing event initiation or determining when specific spectral signature requirements are satisfied (using, say, brightness histograms). Use the detector's output to trigger a recording or information processing scheme. A recording system particularly envisioned centers around the use of a continuous storage loop recorder. Record all sensed data on the loop recorder. The oldest recorded data would be discarded as it is overwritten until an event is detected or a histogram condition is satisfied. When a detector output is sensed the contents of the loop recorder as well as data being generated in real time will be dumped to permanent storage (or to telemetry downlink) until the event is terminated manually or time terminated or terminated when requirements no longer are satisfied.

Benefits Summary

Data savings will be realized primarily in the area of controlling the initiation and termination of the data take. For example, automatic detectors can perform in a rapid response manner. Man cannot respond to a visual stimulus in time to permanently record MSS data. Man must anticipate an upcoming event, land boundary, etc. and thus, the result is to capture more data than needed. Automatic detection would prevent data over capture. Continuous operation of the MSS and recording of the data is prohibitive. Automatic detection would assure capture of every event of like nature; thus, perhaps providing the investigator the best data base for findings. The technique is not state-of-the-art or payload constrained in the sense that detectors for different payloads may be changed out.

A SCREEN TO RECORD ONLY WHEN CONDITION REQUIREMENTS ARE MET

- DETECTORS USED AS CONTINUOUS MONITOR
- PERMANENT STORE ONLY SIGNIFICANT DATA
- ASSURES DATA CAPTURE BEYOND MAN-IN-THE-LOOP RESPONSE LIMITS



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EO-06-S TECHNIQUE NO. 8: GROUND BEACON CONTROL OF DATA TAKE

Functional Description

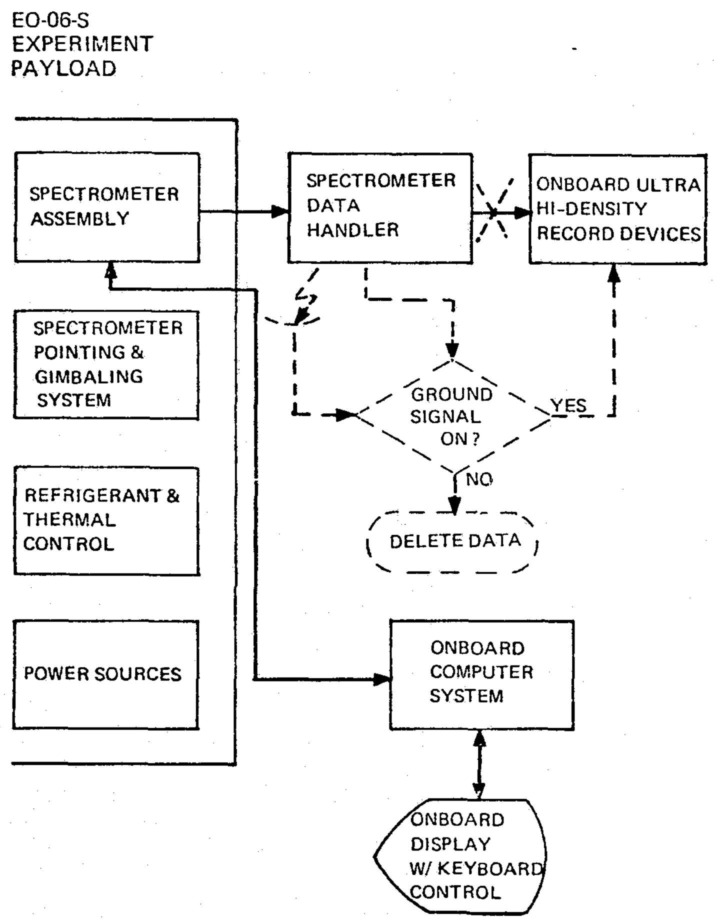
Interviews with various experienced earth resources principle investigators revealed that on occasion despite intensive efforts to obtain a target (especially one slightly off ground track) which required vehicle maneuvers (or would require some off-nadir pointing) that target would be missed (usually had sightings all around the target!). The viewing schedule would not permit sufficient latitude for retakes but in a few cases. This technique then will utilize ground homing beacons to assure critically needed targeting and pointing of the MSS at 'Got to Have it Now Targets' (beacon placement could be facilitated by teams on the field engaged in collecting ground truth data). In areas where viewing once or in consecutive passes is extremely desirable target acquisition by beacon may be very expedient. Examples envisioned might include active volcanic material growth, oil slick progression (caused by man made circumstances or natural), looking for air pollution alert levels over certain highly populated or industrial regions, flood growth in a tributary system, and certain small portions of land such as islands, penisulas, etc.

Benefits Summary

Savings would consist of the elimination of all unnecessarily recorded data obtained while attempting to acquire a MSS view of a particular target based upon visual recognition and manual pointing of the sensor. It would assure acquisition of many 'point' targets that previously were not easily acquired and it would reduce data overtake for those targets that otherwise would have been acquired.

GROUND BEACON CONTROL OF DATA TAKE

- PROVIDES FOR REPEAT OBSERVATION
- STEROSCOPIC VIEW OF TARGET
- ACQUIRE NON-VISIBLE TARGETS



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EO-06-S TECHNIQUE NO. 9: PROCESSOR FOR AUTOMATED DATA TAKE

Functional Description

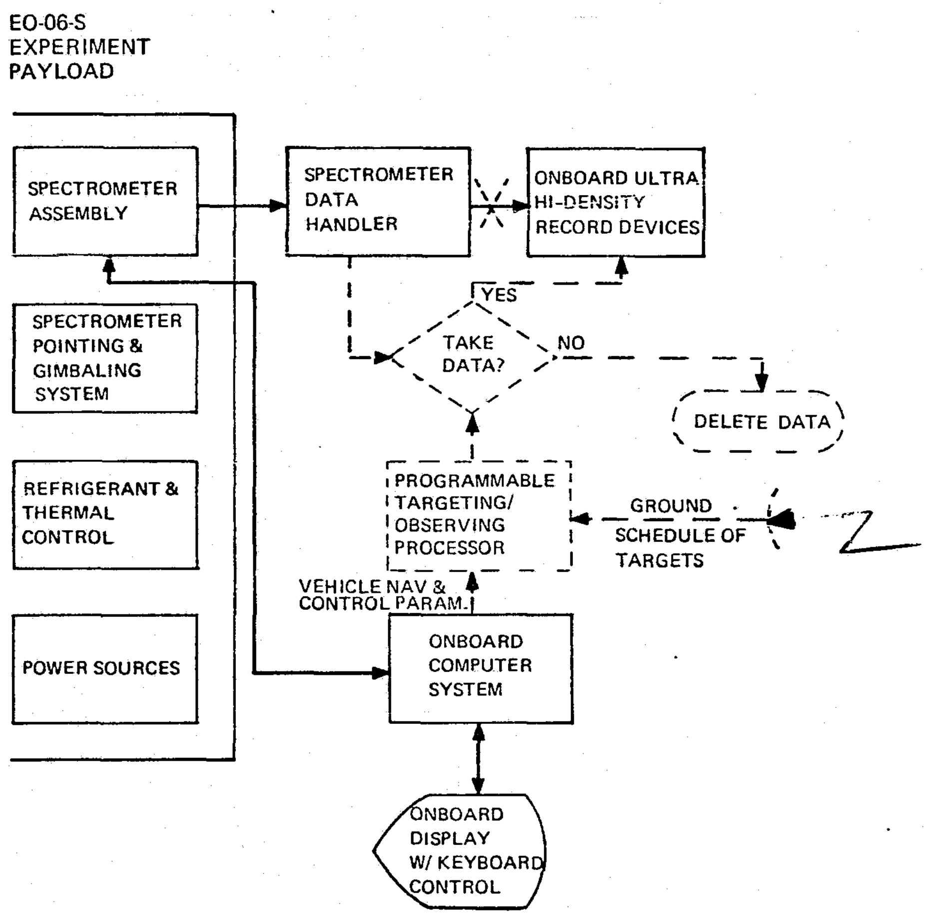
Application of this technique requires the design and development of a universal grid mapping of the planet Earth. Grid coordinates would be provided that can be used to identify mission targets that are locatable by the onboard navigation scheme. Where grid areas might be very large, a target might be described relative to certain grid coordinates. The onboard computers and navigation scheme reference parameters would be used to execute a schedule of experiment operation based upon target coordinates. Computer memory would be used to track which targets scheduled for surveying could not be surveyed due to vehicle control problems, cloud cover, sensor failure, etc. The record of target subjects vs. targets surveyed could be used to automatically, efficiently reschedule the data take for the next target proximity pass. Additionally, alternate proximity targets might be prescribed to be reviewed if primary targets are unobservable. The record of targets to be observed with corresponding coordinates may be fitted into an automated program operated on the ground. Periodic scheduling updates might be made for, say, the next 72 hours of data collection. The ground program would anticipate the upcoming orbital parameters and determine which targets of all the desired targets are feasibly observable in the next 72 hours and their order of observation. The onboard position would schedule any minor maneuvering (for fixed mounted MSS) or the size of the off nadir pointing angle required and make a determination at the scene (by various detecting devices -- see Technique number 7) whether an observation can be made. Subsequent record keeping could be performed onboard or on the ground. Logically, if ground scheduling is performed, any rescheduling should perhaps be done on the ground.

Benefits Summary

Data overtake will be advantageously limited in a severe manner by automatic, scheduled data pass initiation and termination. This will reduce the quantity of data to be stored/telemetered, processed and archived. Release of the astronaut/scientist from the performance of controlling the data take will permit him to make better use of his investigative, exploratory capabilities, by providing him with more time for visual observations and data evaluation and to direct and plan subsequent mission 'free time' (experiment operation time not scheduled for the routine collection of data to support, say, modeling systems and survey/census needs). Implementation would look forward to the time when data users will be the drivers of data collection rather than engineering demonstration and scientific investigations groups.

PROCESSOR FOR AUTOMATED DATA TAKE

- CAPTURES ALL OBSERVABLE TARGETS -- OVERCOMES MANUAL RESPONSE LIMITATION
- CONDITIONALLY SELECTS ALTERNATE TARGETS
- SCHEDULE OF TARGETS IS GROUND UPDATABLE
- REDUCES ONBOARD DATA STORAGE



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EO-06-S TECHNIQUE NO. 10: PROVISION FOR ONBOARD ANALYTICAL TOOLS

Functional Description

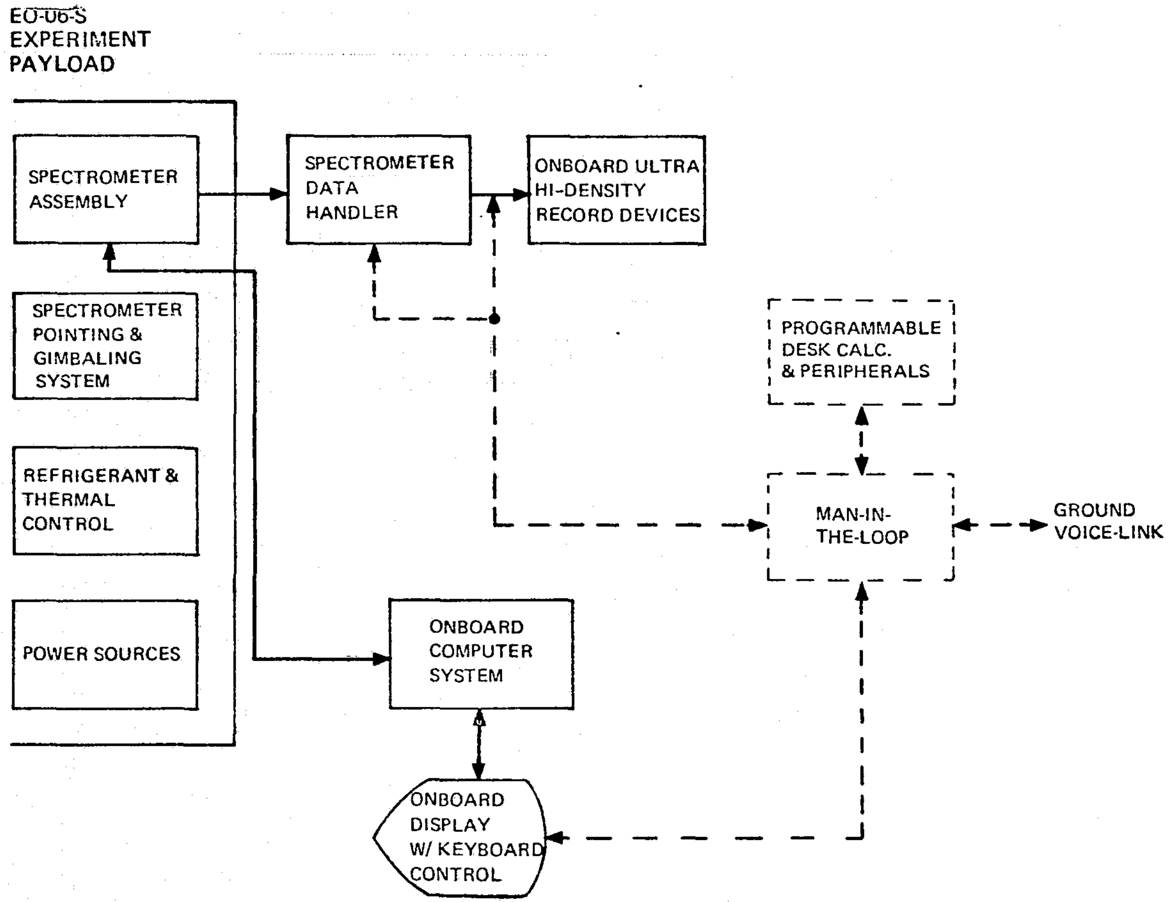
This technique requires that provision be made for onboard programmable, computational capability that is equivalent, for instance, to one of the better desk calculators or mini-computers. The scientists/astronauts are in need of an analytical means of evaluating assorted historical data. This data may come from onboard strip charts, printouts and other onboard hard copy devices (Polaroid pictures, sketches, etc. taken from video displays). Insight into the nature of the data may generate a need to test the hypothesis, generate simple models, to generate algorithms or perfect them by 'fine' tuning' as the hard data develops. Additionally, data might be converted to a different form of the data that is available for onboard use, i.e., printout data to an X, Y plot (obtainable from desk calculation combined with X, Y plotter and/or card readers and cassette memory). Routine calculations may be substantiated with possibly greater accuracy than say with 'personal pocket calculations.' Finally, some justification may be found in using such calculator/computers to monitor and control certain automated experiments which have a low priority but need to be performed at some time during the mission.

Benefits Summary

The technique is a tool needed for its convenience, accessibility and ability to prepare computed output in hard copy onboard the Spacelab (elaborate computation for hypothesis and models would still be expected to be performed by ground support upon consultation). Data savings will be realized by providing the astronaut/scientist the analytical tools essential to the best conduct and planning of experiments.

PROVISION FOR ONBOARD ANALYTICAL TOOLS

- MEANS TO INVESTIGATE, EVALUATE AND GRAPHICALLY PORTRAY ONBOARD DATA
- ADDITIONAL ACCURACY FOR ROUTINE CALCULATION
- PROGRAMMABLE FOR MONITORING AND CONTROL FUNCTION



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EO-06-S TECHNIQUE NO. 11: ONBOARD CORRECTION OF DETECTED NOISE

Functional Description

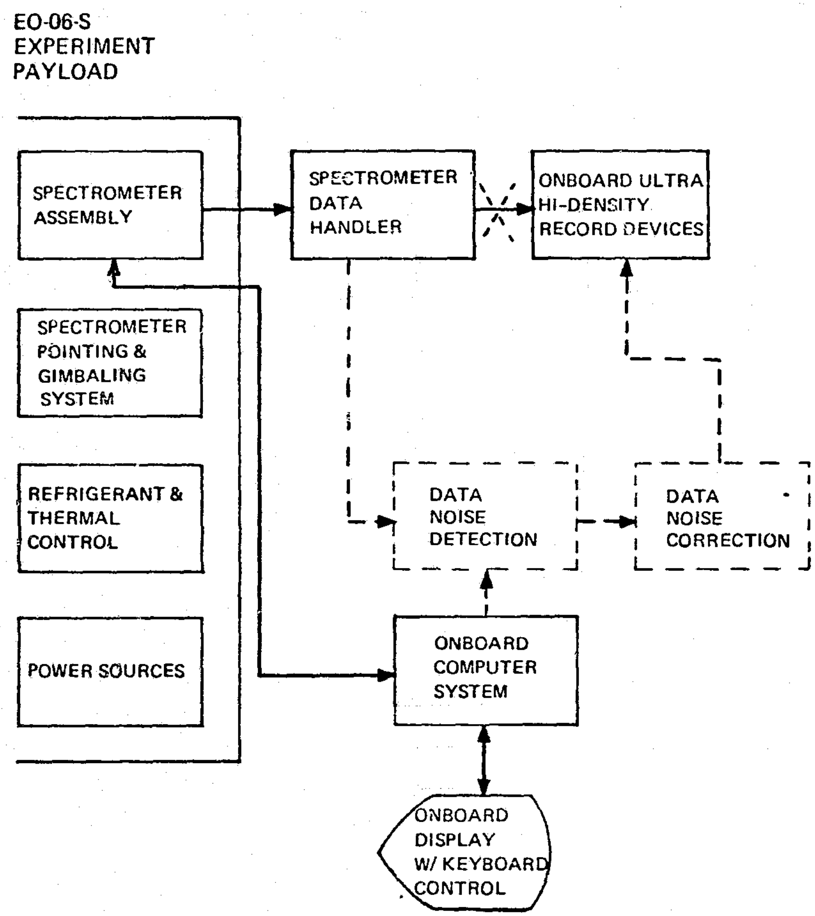
Conversation with principal investigators for Skylab Earth resources experiments revealed significant problems on occasion with electrical noise involving a refrigerant coolant pump. Such problems as this should not need to wait on data reduction to be discovered; consequently requiring considerable computer processing time to remove. This technique would provide for onboard detection, measurement and possible correction of certain electronic, motion and environmental noise sources. Noise correction is suggested via automatic or manually variable filter networks. This would provide the desired flexibility to remove gross effects of noise contaminants of the data prior to data storage and/or computer processing.

Benefits Summary

Early detection and correction of electrical noise contaminants of data before the contaminants promulgates throughout the data will save in the processing of the data. It would also follow that data quality tests can be designed with greater sophistication and resultant greater utility if gross noise contaminants are first removed from the data flow.

ONBOARD CORRECTION OF DETECTED NOISE

- DETECTS, MEASURES, AND ALERTS TO THE PRESENCE OF NOISE
- DATA QUALITY BENEFIT



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EO-06-S TECHNIQUE NO. 12: 'SUB AREA' SCREEN FOR 'FRAME OF INTEREST'

Functional Description

This technique will provide a means to convey only that portion of interest of a CRT displayed 'frame' of data. When a data frame from a MSS channel is displayed (either in real time and 'captured' (see Technique 3) or by recall (see Technique 5), a means of storage or transmitting a reduced portion of data is conceived to be effected by manual selection of only that portion of the frame that is of true investigative interest. Selection of the portion of interest within a 'frame' might be done by a 'light pen' technique whereby the CRT observer encircles the area of interest with the 'light pen' and then only that subset of pixels is stored or telemetered. An alternate means might involve joysticking an expandable rectangle across the screen which would be enlarged to incorporate the area of interest. Then everything bounded by the four corner coordinates of the rectangle would be saved for storage or transmission. 'Man-in-the-loop' interaction then would be accomplished by the scientific observer in his use of the 'light pen' to function in the reduction of the data quantity.

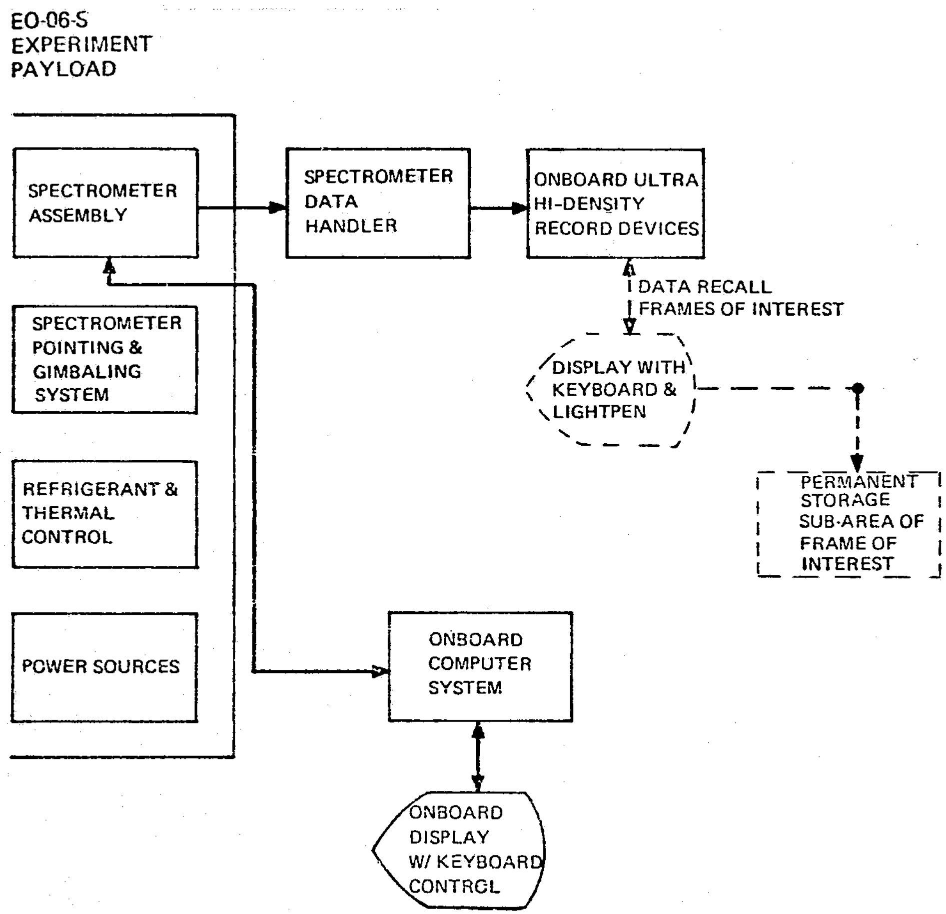
Benefits Summary

Savings will be realized in the reduced quantity of data to be stored and/or processed. Archiving may be simplified and less expensive when specific targets rather than entire frames of data are stored. An intangible benefit appears also, in the opportunity for the telemetering of critical data (which presently does not appear possible) for full scientific community evaluation and technical support or to fulfill an urgent reconnaissance request. Certain aspects of technique implementation already exist. Display systems have been observed in operation whereby a portion of interest in a frame may be selected by light pen or rectangular enclosure and then separately displayed for a 'closeup' or 'enlarged' view or separately treated for image enhancement or spectral analysis.

With onboard CRTs having keyboard controls and with onboard computer processing capability, implementation may be only a growth step beyond other techniques under consideration. It is contemplated that this technique would have application to other payloads or disciplines having imaging devices such as Solar Physics.

'SUB AREA' SCREEN FOR 'FRAME OF INTEREST'

- EXTENSION OF 'QUICK LOOK' SCREEN FOR THE 'FRAME OF INTEREST'
- NO STATE-OF-THE-ART PROBLEM
- REDUCES DATA QUANTITY FOR ONBOARD STORAGE
- AMENABLE TO USE FOR OTHER PAYLOADS



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PHASE 2 SUMMARY

In the process of researching the relevant literature, investigating hardware characteristics, contacting local data users, and pursuing the information gathering trips, several ideas for optimizing a remotely sensed data processing system were formed. Some of these ideas were developed into new interaction techniques and others confirmed techniques previously conceived. A summary of these ideas which were used to support the techniques previously discussed is contained in the following paragraphs.

More extensive onboard and ground video display capability is desirable. Multiple CRT screens could be used to display image data in different wavelengths, present and historical data for visual comparisons, and for variable support data visibility. For some applications simultaneous ground and onboard visibility is required.

Both the Skylab crew and their immediate support elements recommended that additional interactive controls should be charged to the onboard crew. The Skylab program involved a series of activities that somewhat constrained the flexibility of the crew and limited their effectiveness in advancing the scientific return for the mission.

Many of the ERTS and Skylab data users were concerned that vehicle attitude information was either inadequate or extremely delayed in delivery to users. Steps should be taken to make timely separate delivery of this attitude information or to consolidate some attitude data into the scientific data stream.

During the Skylab mission the crew time was monopolized by proceduralized activities. In order to optimize crew utility in supporting experiment goals, automation should be applied to activities whenever possible.

Much of the data generated by recently developed sensors for the acquisition of remotely sensed data has been somewhat difficult to process through the telemetry and data reduction steps. The data processing community feels strongly that substantial savings would result from instrument design being influenced by data transmission and reduction considerations.

On past missions, the emphasis on operational considerations resulted in excessive engineering data being telemetered. In some instances the engineering data was telemetered at a rate which exceeded the ground processing capability. Emphasis has somewhat shifted to scientific interests and the telemetered data should be allocated accordingly.

Experiment sensor calibration status has proven to be one of the most prominent factors in determining scientific data quality. Primary calibration sources have sometimes been lost or rendered ineffective on past missions. Secondary calibration sources should be located onboard for use in sustaining data quality.

Crew activities in effecting the experiment and data management are somewhat involved and hence subject to misdirection. Consideration should be given to the development and use of self test procedures for the crew to verify proper experiment management.

The Skylab crew alert system involved extensive use of visual means of indicating potential problem areas. Crew detection often required periodic status checks which was difficult during high activity periods. The visual alerts should be replaced by audible alarms which would free the crew to concentrate on other procedures.

In some instances, data generated by remotely sensing instruments has been found to be incompatible with the associated ground data processing systems. This problem could be alleviated by utilizing more pre-mission data flow simulations to ensure compatibility between sensors and data processing systems design.

PHASE 2 SUMMARY

- EXPAND THE ONBOARD AND GROUND VIDEO DISPLAY CAPABILITIES
- INCLUDE ONBOARD INTERACTION CONTROLS FOR CREW
- MAKE ENGINEERING AND OPERATIONS INFORMATION MORE READILY AVAILABLE TO PI's
- AUTOMATE AS MANY ROUTINE PROCEDURES AS POSSIBLE
- FORCE SENSOR DESIGN TO CONSIDER TELEMETRY AND DATA REDUCTION DIFFICULTIES
- AVOID EXCESSIVE TELEMETRY OF ENGINEERING DATA
- DEVELOP SECONDARY ONBOARD CALIBRATION SCHEMES
- INCORPORATE AND USE CREW SELF CHECK PROCEDURES FOR EXPERIMENT OPERATIONS
- REPLACE MORE VISUAL ALERTS WITH AUDIBLE ALARMS
- UTILIZE EARLY PRE-MISSION SIMULATION OF DATA FLOW IN DATA SYSTEM DESIGN

OTHER FINDINGS AND RECOMMENDATIONS

During the course of interviews that were obtained to fulfill the objectives of the User Interaction Study, useful extremely relevant suggestions often were made that seem of importance to us to have 'put on record' for the benefit of the Shuttle Spacelab program. These suggestions did not have direct bearing on 'interaction' per se but do have bearing on the Shuttle/Spacelab data flow. The interviewees were people of note in their respective areas of prior work (Skylab, ERTS, etc.) and had acquired knowledge by experience (the hard way!). Their acquired expertise is herein noted lest it be lost in the slow shuffle of time.

The scientific/user community that has little or no prior space-flown sensor experience must be made aware and be more than passingly acquainted with the kind of data that would most likely really be generated by their sensors. Noisy, dynamic, intermittent data is difficult to compress, will impact data flows and slow processing and evaluation.

An improvement in communications of experimenters with sensors on a multi-discipline or multi-sensor, single discipline payload could improve the choice, sampling rate and resolution of engineering data and certain experiment generated parameters useful to other experimenters. Forethought, discussion, and mutual advice in this area will expedite ground processing (and possible reconstruction) of scientific data and also improve the operational environment of mission conduct and scheduling.

It is suggested that telemetry format changes must be viewed in terms of already sized hardware on the ground. This is illustrated by the fact that parameter ranges were increased as sensor ranges were extended but with no corresponding changes in the originally requested resolution. This of course unduly forced 8-bit words to 12-bit words or 12-bit words to 16-bit words, etc.

Decreasing the opportunities for conducting an experiment on an assumptive basis in any way will enhance chances for experiment success. Thus, the recommendation that if at all practical the one who sets up an experiment should run it. Shift hand-off experience reveals occasions of experiments being performed that were not completely calibrated, set-up, etc.

Duplication of data passes can be eliminated by exercising better oversight, planning, and coordination of data requests being generated within the community of a given discipline. Timely receipt of data could be improved and archiving costs reduced by an awareness that a given data request may already be satisfiable or will be satisfiable by another or different sensor that is flying or will fly, i.e. a survey for sea lions may be duplicated :hin a recent search for blue whales, etc.

OTHER FINDINGS AND RECOMMENDATIONS

- DEVELOP REALISTIC EXPECTATIONS IN THE SCIENTIFIC/USER COMMUNITY AS TO THE 'REAL WORLD' NATURE OF THEIR DATA
- ESTABLISH COMMUNICATION BETWEEN EXPERIMENTERS ABOUT MUTUAL (INTERLOCKED) DATA REQUIREMENTS
- RANGE OF DATA WORDS SHOULD BE KEPT COMPATIBLE WITH RESOLUTION REQUESTED
- EXPERIMENT SETUP AND EXECUTION RUN BY SAME SHIFT
- COORDINATE EXISTING DATA REQUESTS WITH ANTICIPATED, BUT DELAYED, DATA REQUESTS

IBM

Genuine need exists for forethought, planning and simulations to develop the tools that can look at real time data (scientific, housekeeping and engineering) and aid the evaluation in ascertaining engineering trustworthiness of orbiting sensors and other hardware. High data rates and complex modes of performance complicate the development cycle. Simulation and engineering data tools development will aid in forcing data flow requirements (i.e. establishing minimum data need and means to get it to the engineering team). Engineering data evaluation efforts can force sensor changes that will improve actual scientific data processing.

An opinion expressed that encompasses a number of past program's difficulties that shows great promise for the Shuttle era is "Stop the use of sensors that are only one step removed from laboratory models, instruments that are results of much circumstantial improvisation to primarily 'sense' data. Design sensors, the capability now exists, from end-to-end with the view of a data-efficient operation in mind."

The Skylab experience indicated that without additional outside influence, mantended operation of remote sensing instruments sometimes results in extraneous data being collected. This scheme would involve more efficient experiment data management via a proceduralized plan for data collection. The plan would specify those conditions under which collected data would be of little or no value and would be formulated in cooperation with the experiment sponsors.

Decrementing timers could be used to effect more efficient event scheduling. Using the timers to assist the crew with the initiation and termination of data takes would be relatively simple to implement. The timers, as many as are needed, would be initialized by the onboard crew or ground control to a predetermined value and allowed to count down. When the timers count to zero, an alert would be sounded to initiate crew action to redirect the experiment or to manage the collection of data.

OTHER FINDINGS AND RECOMMENDATIONS (continued)

- DEVELOP ENGINEERING EVALUATION TOOLS BEFORE FIRST ENGINEERING FLIGHTS
- DESIGN INSTRUMENTS BEYOND THE LAB SENSOR LEVEL TO ACCOMMODATE REPLACEMENT OR CHANGE AND TO BE DATA EFFICIENT
- PROCEDURALIZE PLANS FOR OPTIMUM DATA COLLECTION
- MAKE GENEROUS USE OF DECREMENTING TIMERS

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FUTURE WORK

Phase 3 of the Spacelab User Interaction Study, due for Completion August 31, will result in a preliminary design of an interaction system for each of the two baseline payloads utilizing the concepts developed in Phase 2. The design will consider individual techniques and will result in a description of the new hardware or hardware modifications, the definition of software functional requirements, a timeline of implementation and/or operations procedures, and a summary of cost considerations.

The completion of Phase 3 will represent the starting point for incorporation of interaction into Spacelab data system design. Follow-on effort is proposed that is necessary for the ultimate implementation. These include:

- Utilizing the current study results, generate an interaction demonstration implementation plan. Previous studies have been theoretical in nature and the recommended techniques and concepts should be demonstrated prior to implementation and integration into onboard and ground systems. This task will define a systems plan to validate the interaction concepts and include the associated demonstration.

- Expand the baseline interaction system to include all payloads within the respective baseline disciplines. Resulting output would be a broader more general interaction system definition applicable to both of the baseline disciplines (Earth Resources and Solar Physics).

- Perform compatibility studies to design an interaction system for multi-discipline payloads. The baseline discipline interaction system will be modified to generate a distinct system applicable to all the Spacelab experiment disciplines.

- Integrate the final interaction system into the total Spacelab data flow. This would involve an investigation to determine the impacts on the Spacelab subsystems resulting from implementation of the interaction system. This study would benefit from the time delay to perform the other tasks in that the Spacelab experiment and subsystem definition should evolve significantly and the Spacelab scientific principal investigator designations should be complete. Pacing items for the integration and implementation study would be allowed to mature.

FUTURE WORK

PHASE 3 (COMPLETE BY AUGUST 31)

- PAYLOAD CONCEPT SELECTION
- HARDWARE DESCRIPTION
- SOFTWARE REQUIREMENTS
- IMPLEMENTATION/OPERATION PROCEDURES
- COST CONSIDERATIONS

FOLLOW-ON

- DEMONSTRATION
- EXPANSION TO INCLUDE ALL EXPERIMENTS OF BASELINE PAYLOADS
- APPLICATION TO MULTI-DISCIPLINE PAYLOADS
- INTEGRATION INTO TOTAL SPACELAB DATA FLOW